

# 2013 Title 24

## Nonresidential ACM Reference Manual

### Notes to Reviewers:

This draft of the Nonresidential ACM starts with the July PAC workshop. Tracked changes are relative to earlier versions of the 2013 ACM, which include both COMNET and 2008 NACM rules.

Grey Shaded      This is material from the California NACM that has not yet been integrated into the document.

**NOTES**      **RED NOTES ARE USED TO IDENTIFY MATERIAL OR MARK PLACES WHERE MATERIAL HAS BEEN MOVED TO AN APPENDIX BUT NOT SIGNIFICANTLY CHANGED.**

Magenta Highlight      Text indicates documentation requirement, to be moved to separate section per CEC requirements.

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# 1. Overview

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## 1.1 Purpose

This document is the California Nonresidential ACM Reference Manual. It explains the requirements for approval of nonresidential compliance and Compliance Software in California. Approved software is used for two purposes: to demonstrate minimum Compliance with the California energy efficiency standards and to achieve beyond-code energy performance needed to qualify for Reach standards. The procedures and processes described in this manual are designed to provide consistency and accuracy while preserving the integrity of the process of Compliance and Reach. This manual addresses software for nonresidential buildings, hotels & motels, and high-rise residential buildings as outlined in Title 24, Part 6, Subchapter 5, § 140.1. A separate ACM Reference Manual applies to low-rise residential buildings. The approval process for nonresidential software programs is specified in Title 24, Part 1, § 10-101 through § 10-110 of the California Code of Regulations.

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## 1.2 Modeling Assumptions

When calculating annual energy use, it is necessary to make assumptions about how the proposed building is operated. Operating assumptions include thermostat settings, number of occupants, receptacle loads, process loads, hot water loads as well as schedules of operation for HVAC systems, lighting systems and other systems. Sometimes these data are known with some certainty and other times (for instance for speculative buildings), it is necessary to make estimates. Some of these inputs are prescribed (they are fixed for both the proposed design and for the baseline building and can't be changed), while others are defaults for California Compliance and for California Reach.

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## 1.3 Scope

This manual is intended to be used for nonresidential buildings that are seeking a building permit for new construction or are seeking recognition under California's Reach program.

The long-term goal of this manual is to define modeling rules and procedures for all conceivable design features that may be incorporated in buildings. The authors recognize, however, that this goal cannot be fully achieved due to limitations in the development energy simulation algorithms, and due to the natural lag time between the introduction of an advanced energy efficiency measure or device and the development of algorithms to simulate its performance.

The goal of the manual is to provide methods that are as consistent and accurate as possible. This goal can best be achieved if the manual is a 'living document,' changing and growing as increasing amounts of information and better modeling methods become available.

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## 1.4 Organization

This document is organized in five chapters and several appendices, as described below:

Chapter	Description
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1. Overview	The purpose, organization, content, and intent of the manual (this chapter).
2. General Modeling Procedures	An overview of the modeling process, outlining the modeling rules and assumptions that are implemented in the same way for both the standard design and the proposed design, and procedures for determining system types and equipment sizes.
3. Software Requirements	Requirements for the simulation engines and software shells that are used to make calculations, and special reporting requirements for non-standard building features.
4. Content and Format of Standard Reports	The content and organization of the standard reports that need to be produced by qualifying software.
5. Building Descriptors Reference	The acceptable range of inputs for the proposed design and a specification for the standard design.

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In addition, a number of appendices are provided that contain reference material that support definition of the standard design. The numbering for these appendices generally aligns with the section numbers in the main manual that reference the appendices.

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## 1.5 California ACM

The reference procedures and method described in this manual establish the basis of comparison for all software. The approval process ensures that a minimum level of energy efficiency is achieved regardless of the software used. This is accomplished

- by having candidate software pass a series of Reference Method comparison tests,
- by specifying input which may be varied in the compliance process for credit and which inputs are fixed or restricted,
- by defining standard reports output requirements, and
- by software vendor-certification to the requirements in this manual.

The Nonresidential ACM Reference Manual is an approved document, separate from the formally adopted ACM regulations. This gives the Commission the flexibility to incorporate new modeling procedures or features, or fix any errata, within the code cycle. The document is said to be in continuous maintenance. Software may be certified with the capability of modeling specific building systems or features.

The Commission's purpose in approving additional capabilities is to accommodate new technologies which have only begun to penetrate the market and new modeling algorithms. Newly added capabilities which evaluate measures already in relatively common use shall have their standard design for the measure based on the common construction practice (or the typical base situation) for that measure since common practice is the inherent basis of the standards for all measures not explicitly regulated. For example, the Commission has no interest in an optional capability that evaluates the energy impacts of dirt on windows unless a new technology produces substantial changes in this aspect of a building relative to buildings without this technology. The burden of proof that an additional capability should be approved lies with the applicant.

Companion documents which are helpful to prepare software for certification include the latest editions of the following Commission publications:

- Energy Efficiency Standards
- Appliance Efficiency Regulations
- Nonresidential Compliance Manual
- Nonresidential Alternative Calculation Method (ACM) Manual
- Reference Nonresidential Appendices
- Reference Joint Appendices

In this manual the term "Standards" means the Building Energy Efficiency Standards, Title 24, Part 6 of the California Code of Regulations. The term "compliance" means that a building design in an application for a building permit complies with the "Standards" and meets the requirements described for building designs therein.

There are a few special terms that are used in this Manual. The Commission approves the use of software for compliance. Commission approval means that the Commission accepts the applicant's certification that software meets the requirements of this Manual. The proponent of candidate software is referred to as a vendor. The vendor shall follow the procedure described in this document to publicly certify to the Commission that the software meets the criteria in this document for:

- Accuracy and reliability when compared to the Reference Method; and
- Suitability in terms of the accurate calculation of the correct energy budget, the printing of standardized forms, and the documentation on how the program demonstrates compliance.

In addition to explicit and technical criteria, Commission approval will also depend upon the Commission's evaluation of:

- Enforceability in terms of reasonably simple, reliable, and rapid methods of verifying compliance and application of energy efficiency features modeled by the software and the inputs used to characterize those features by the software users.
- Dependability of the installation and energy savings of features modeled by the software. The Commission will evaluate the probability of the measure actually being installed and remaining functional. The Commission shall also determine that the energy impacts of the features that the software is capable of modeling will be reasonably accurately reflected in real building applications of those features. In particular, it is important that the software does not encourage the replacement of actual energy savings with theoretical energy savings due to tradeoffs allowed by the software.

For the vendor, the process of receiving approval of software includes preparing an application, working with the Commission staff to answer questions from either Commission staff or the public, and providing any necessary additional information regarding the application. The application includes the four basic elements outlined below. The Commission staff evaluates the software based on the completeness of the application and its overall responsiveness to staff and public comment.

The four basic requirements for approval include:

1. Required capabilities:

Software shall have all the required input capabilities explained in Chapter 2.

Software may meet software requirements and documentation requirements described in Chapter 3.

2. Accuracy of simulation:

The software shall demonstrate acceptable levels of accuracy by performing and passing the required certification tests discussed in Chapter 6.

The software vendor performs the certification tests in Chapter 6. The vendor conducts the specified tests, evaluates the results and certifies in writing that the software passes the tests. The

Commission will perform spot checks and may require additional tests to verify that the proposed software is appropriate for compliance purposes.

When energy analysis techniques are compared, two potential sources of discrepancies are the differences in user interpretation when entering the building specifications, and the differences in the software's algorithms (mathematical models) for estimating energy use. The approval tests minimize differences in interpretation by providing explicit detailed descriptions of the test buildings that must be analyzed. For differences in the software's algorithms, the Commission allows algorithms that yield equivalent results.

### 3.. Program support:

The vendor shall provide ongoing user and enforcement agency support as described in the Nonresidential ACM Approval Manual.

The Commission may hold one or more workshops with public review and vendor participation to allow for public review of the vendor's application. Such workshops may identify problems or discrepancies that may necessitate revisions to the application.

Commission approval of software programs is intended to provide flexibility in complying with the Standards. However, in achieving this flexibility, the software shall not degrade the standards or evade the intent of the Standards to achieve a particular level of energy efficiency. The vendor has the burden of proof to demonstrate the accuracy and reliability of the software relative to the reference method and to demonstrate the conformance of the software to the requirements of this manual.

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## 1.6 Compliance

### 1.6.1 Type of Project Submittal

Software shall require the user to identify the type of project; either Compliance or Reach. The software shall require the user to choose one of the following options:

- New Building or Addition Alone. Software may do this by treating an addition alone as a new building, but an addition modeled in this way shall be reported on all output forms as an Addition (modeled alone).
- Addition Plus Alteration of Existing Building. (if software is approved for this optional capability)
- Alteration of Existing Building (if software is approved for this optional capability)

### 1.6.2 Scope of Compliance Calculations

For each building or separately permitted space, software shall also require the user to identify the scope of the compliance submittal from the following list:

- Envelope only
- Mechanical only
- Envelope and Lighting
- Envelope and Mechanical
- Lighting and Mechanical
- Envelope, Lighting and Mechanical

Each of these situations requires specific assumptions, input procedures and reporting requirements. Modeling assumptions are documented in Chapter 5. Reporting requirements are documented in Chapter

4. Software shall only produce compliance reports specific to the scope of the submittal determined for the run. For example, an Envelope Only scope run is only allowed to produce ENV forms and PERF forms that are designated Envelope Only.

The information about installed service water heating system(s) is included in the mechanical compliance submittal forms. Software shall calculate the energy use for both the proposed system(s) and the reference system(s) [TDV energy budget] and provide the results on the PERF forms. The energy budget is calculated in accordance with Section 5.9 (Service Water Heating--Required capabilities) of this manual. If the energy used by the proposed water heating system(s) is less than the energy budget, the credit may be traded off for other building features. Alternatively, for high-rise residential buildings, users may show service water heating compliance by meeting the prescriptive requirements of § 150.1(f)(8). When the compliance for the service water heating is shown prescriptively, tradeoff between the service water heating and other building components is not allowed.

When a building has a mixed scope of compliance, such as a speculative building where all the envelope is being permitted but the core includes lighting as well as portions of the envelope, two (or more) compliance runs shall be performed and forms from different runs shall be submitted for the appropriate spaces. The scope of submittal for the building core compliance run will be Envelope & Lighting and the scope of submittal for the compliance run for the remainder of the building will be Envelope Only.

The following modeling rules apply for when the scope of the compliance calculations do not include one of the following: the building envelope, the lighting system or the mechanical system.

*Table 1: Compliance Options*

Cases	Modeling Rules for Proposed Design	Modeling Rules for Standard Design (All):
No Envelope Compliance Mechanical Only Lighting and Mechanical	The envelope shall be modeled according to the as-built drawings and specifications of the building or as it occurs in the previously-approved compliance documentation of the building. All envelope features and inputs required for software by this manual shall be entered.  Note: A partial permit application involving no envelope compliance creates an exceptional condition. This requires either a copy of the previous envelope compliance approval or an equivalent demonstration by the applicant (to the satisfaction of the local enforcement agency) that the building is conditioned and an occupancy permit has previously been issued by the local enforcement agency. The exceptional condition list shall indicate the presence of an existing or previously-approved envelope documentation and a form shall be produced to document the existing envelope. Software shall not produce envelope (ENV) compliance forms when the user selects this option.	The envelope shall be identical to the proposed design.
No Mechanical Compliance Envelope Only Envelope and Lighting	Software shall model the baseline building HVAC system according to the rules in Chapter 5.	The mechanical systems shall be identical to the proposed design.
No Lighting Compliance Envelope Only Mechanical Only	Previously-approved lighting plans with approved lighting compliance forms may be entered. The exceptional conditions list on the PERF-1 form shall indicate that previously-approved lighting plans	The baseline building lighting system shall be identical to the proposed design.

Envelope and Mechanical	and compliance forms shall be resubmitted with the application.
	<div>In the absence of approved lighting plans and lighting compliance forms, the software shall model the baseline building lighting system.</div> <div>The baseline building lighting system shall be identical to the proposed design.</div>

### 1.6.3 Climate Zones

The program shall account for variations in energy use due to the effects of the sixteen (16) California climate zones and local weather data. Climate information for compliance simulations shall use one of sixteen (16) data sets described in Reference Joint Appendix JA2.

### 1.6.4 Time Dependent Valuation

The candidate software shall calculate the hourly energy use for both the standard design and the proposed design by applying a TDV factor for each hour of the reference year. TDV factors have been established by the CEC for residential and nonresidential occupancies, for each of the climate zones, and for each fuel (electricity, natural gas, and propane). The procedures for Time Dependent Valuation of energy are documented in Reference Appendix JA3.

## 1.7 Approval Process

### 1.7.1 Application Checklist

The following items shall be included in an application package submitted to the Commission for software approval:

- Compliance Software Vendor Certification Statement. A copy of the statement contained in Appendix A, signed by the software vendor, certifying that the software meets all Commission requirements, including accuracy and reliability when used to demonstrate compliance with the energy standards.
- Computer Runs. Copies of the computer runs specified in Chapter 3 of this manual on machine readable form as specified in Chapter 3 to enable verification of the runs.
- Help System and/or User's Manual. The vendor shall submit a complete copy of the help system and/or software user's manual, including material on the use of the software for compliance purposes.
- Copy of the Compliance Software and Weather Data. A machine readable copy of the software for random verification of compliance analyses. The vendor shall provide weather data for all 16 climate zones.
- TDV Factor Documentation. The software shall be able to apply the TDV multipliers described in Reference Appendix JA3.
- Application Fee. The vendor shall provide an application fee of \$2,000.00 (two thousand dollars) as authorized by § 25402.1(b) of the Public Resources Code, made out to the "State of California" to cover costs of evaluating the application and to defray reproduction costs.

A cover letter acknowledging the shipment of the completed application package should be sent to:

Executive Director  
California Energy Commission

1516 Ninth Street, MS-39  
Sacramento, CA 95814-5512

Two copies of the full application package should be sent to:

Compliance Software Nonresidential Certification  
California Energy Commission  
1516 Ninth Street, MS-26  
Sacramento, CA 95814-5512

Following submittal of the application package, the Commission may request additional information pursuant to Title 24, Part 1, § 10-110. This additional information is often necessary due to complexity of software. Failure to provide such information in a timely manner may be considered cause for rejection or disapproval of the application. A resubmittal of a rejected or disapproved application will be considered a new application, including a new application fee.

## **1.7.2 Types of Approval**

This Manual addresses two types of software approval: full program approval (including amendments to programs that require approval), and approval of new program features and updates.

If software vendors make a change to their programs as described below, the Commission shall again approve the program. Additionally, any software change that affects the energy use calculations for compliance, the modeling capabilities for compliance, the format and/or content of compliance forms, or any other change which would affect Compliance or Reach requires another approval.

Changes that do not affect Compliance or Reach, such as changes to the user interface, may follow a simplified or streamlined procedure for approval. To comply with this simpler process, the software vendor shall certify to the Commission that the new program features do not affect the results of any calculations performed by the program, shall notify the Commission of all changes and shall provide the Commission with one updated copy of the program and Help System/User's Manual. Examples of such changes include fixing logical errors in computer program code that do not affect the numerical results (bug fixes) and new interfaces.

### **1.7.2.1 Full Approval & Re-Approval of Compliance Software**

The Commission requires program approval when candidate software has never been previously approved by the Commission, when the software vendor makes changes to the program algorithms, or when any other change occurs that in any way affects the compliance results. The Commission may also require that all currently approved software be approved again whenever substantial revisions are made to the Standards or to the Commission's approval process.

The Commission may change the approval process and require that all software be approved again for several reasons including:

- If the standards undergo a major revision that alters the basic compliance process, then software would have to be updated and re-approved for the new process.
- If new analytic capabilities come into widespread use, then the Commission may declare them to be required software capabilities, and may require all software vendors to update their programs and submit them for re-approval.

When re-approval is necessary, the Commission will notify all software vendors of the timetable for renewal. A new version of this manual will be published and the Commission will provide instructions for re-approval.

Re-approval shall be accompanied by a cover letter explaining the type of amendment(s) requested and copies of other documents as necessary. The timetable for re-approval of amendments is the same as for full program approval.

### **1.7.2.2 Approval of New Features & Updates**

Certain types of changes may be made to previously approved nonresidential software through a streamlined procedure, including implementing a computer program on a new machine and changing executable program code that does not affect the results.

Modifications to previously approved software including new features and program updates are subject to the following procedure:

- The software vendor shall prepare an addendum to the Compliance Supplement or software user's manual, when new features or updates affect the outcome or energy efficiency measure choices, describing the change to the software. If the change is a new modeling capability, the addendum shall include instructions for using the new modeling capability for compliance.
- The software vendor shall notify the Commission by letter of the change that has been made to the software. The letter shall describe in detail the nature of the change and why it is being made. The notification letter shall be included in the revised Compliance Supplement or software user's manual.
- The software vendor shall provide the Commission with an updated copy of the software and include any new forms created by the software (or modifications in the standard reports).

The Commission will respond within 45 days. The Commission may approve the change, request additional information, refuse to approve the change, or require that the software vendor make specific changes to either the Compliance Supplement addendum or the software program itself.

With Commission approval, the vendor may issue new copies of the software with the Compliance Supplement addendum and notify software users and building officials.

### **1.7.3 Challenges**

Building officials, program users, program vendors, Commission staff or other interested parties may challenge any nonresidential software approval. If any interested party believes that a compliance program, an algorithm or method of calculation used in a compliance program, a particular capability or other aspect of a program provides inaccurate results or results which do not conform to the criteria described in his manual, the party may initiate the challenge of the program.

### **1.7.4 Decertification of Compliance Software Programs**

The Commission may decertify (rescind approval of) an alternative calculation method through the following means:

- All software programs are decertified when the Standards undergo substantial changes which occur about every three years.
- Any software can be decertified by a letter from the software vendor requesting that a particular version (or versions) of the software be decertified. The decertification request shall briefly describe the nature of the program errors or "bugs" which justify the need for decertification.
- Any "initiating party" may commence a procedure to decertify an software according to the steps outlined below. The intent is to include a means whereby unfavorable software tests, serious program errors, flawed numeric results, improper forms and/or incorrect program documentation not discovered in the certification process can be verified, and use of the particular software version discontinued. In this process, there is ample opportunity for the Commission, the software vendor and all interested parties to evaluate any alleged problems with the software program.

NOTE 1: The primary rationale for a challenge is unfavorable software tests, which means that for some particular building design with its set of energy efficiency measures, the software fails to meet the criteria used for testing software programs described in Chapter 3.

NOTE 2: Flawed numeric results where the software meets the test criteria in Chapter 3, in particular when software fails to properly create the baseline building.

Following is a description of the process for challenging software or initiating a decertification procedure:

1. Any party may initiate a review of software's approval by sending a written communication to the Commission's Executive Director. (The Commission may be the initiating party for this type of review by noticing the availability of the same information listed here.)

The initiating party shall:

- State the name of the software and the program version number(s) which contain the alleged errors;
  - Identify concisely the nature of the alleged errors in the software which require review;
  - Explain why the alleged errors are serious enough in their effect on analyzing buildings for compliance to justify a decertification procedure; and,
  - Include appropriate data on any media compatible with Windows XP or above and/or information sufficient to evaluate the alleged errors.
2. The Executive Director shall make a copy or copies of the initial written communication available to the software vendor and interested parties within 30 days.
  3. Within 75 days of receipt of the written communication, the Executive Director may request any additional information needed to evaluate the alleged software errors from the party who initiated the decertification review process. If the additional information is incomplete, this procedure will be delayed until the initiating party submits complete information.
  4. Within 75 days of receipt of the initial written communication, the Executive Director may convene a workshop to gather additional information from the initiating party, the software vendor and interested parties. All parties will have 15 days after the workshop to submit additional information regarding the alleged program errors.
  5. Within 90 days after the Executive Director receives the application or within 30 days after receipt of complete additional information requested of the initiating party, whichever is later, the Executive Director shall either:
    - Determine that the software need not be decertified; or,
    - Submit to the Commission a written recommendation that the software be decertified.
  6. The initial written communication, all other relevant written materials, and the Executive Director's recommendation shall be placed on the calendar and considered at the next business meeting after submission of the recommendation. The matter may be removed from the consent calendar at the request of one of the Commissioners.
  7. If the Commission approves the software decertification, it shall take effect 60 days later. During the first 30 days of the 60-day period, the Executive Director shall send out a Notice to Building Officials and Interested Parties announcing the decertification.

All initiating parties have the burden of proof to establish that the review of alleged software errors should be granted. The decertification process may be terminated at any time by mutual written consent of the initiating party and the Executive Director.

As a practical matter, the software vendor may use the 180- to 210-day period outlined here to update the software program, get it re-approved by the Commission, and release a revised version that does not have the problems initially brought to the attention of the Commission. Sometimes the software vendor may wish to be the initiating party to ensure that a faulty program version is taken off the market

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## **1.8 Vendor Requirements**

Each vendor shall meet all of the following requirements as part of the software approval process and as part of an ongoing commitment to users of their particular program.

### **1.8.1 Availability to Commission**

All software vendors are required to submit at least one fully working program version of the software to the California Energy Commission. An updated copy or access to the approved version of the software shall be kept by the Commission to maintain approval for compliance use of the software.

The Commission agrees not to duplicate the software except for the purpose of analyzing it, for verifying building compliance with the compliance software, or to verify that only approved versions of the software are used for compliance.

### **1.8.2 Enforcement Agency Support**

Software vendors shall provide a copy of the software User's Manual / Help System to all enforcement agencies who request one in writing.

### **1.8.3 User Support**

Software vendors shall offer support to their users with regard to the use of the software for Compliance or Reach purposes. Vendors may charge a fee for user support.

### **1.8.4 Compliance Software Vendor Demonstration**

The Commission may request software vendors to offer a live demonstration of their software's capabilities. One or more demonstration may be requested before approval is granted.

## 2. General Modeling Procedures

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### 2.1 General Requirements for Data from the User

#### 2.1.1 General

This document lists the building descriptors that are used in the compliance simulation. Users must provide valid data for all descriptors that do not have defaults specified and that apply to parts of the building that must be modeled.

#### 2.1.2 Building Envelope Descriptions

The user shall provide accurate descriptions for all building envelope assemblies including exterior walls, windows, doors, roofs, exterior floors, slab-on-grade floors, below grade walls and below grade floors. The user shall provide data for all of the required descriptors listed in section 5.5 that correspond with these assemblies. However, the following exceptions apply:

- Exterior surfaces whose azimuth orientation and tilt differ by no more than 45° and are otherwise the same may be described as a single surface or described using multipliers. This specification would permit a circular form to be described as an octagon.

#### 2.1.3 Space Use Classification

The user must designate space use classifications that best match the uses for which the building or individual spaces within the building are being designed. Space use classifications determine the default or prescribed occupant density, occupant activity level, receptacle power, service water heating, lighting load, area-based minimum outdoor ventilation air, daylighting setpoints, and operating schedules used in the analysis. Process loads and refrigeration loads are also provided for applicable space types.

The user must specify the space use classifications using either the complete *building* or *area category* methods but may not combine the two types of categories within a single analysis. The building area method assigns assumptions based on average values that occur within typical buildings of the designated type. The complete building method is recommended for use when detailed space planning information is unavailable. More than one building area category may be used in a building if it is a mixed-use facility.

The area category method uses the area category categories in the standard design, which were developed for lighting requirements. The area category method requires area category entry of floor area and space use designations. The area category method can be used whenever design information is available with the necessary detail.

The user may override the default assumptions for some building descriptors dependent on the space use classification with supporting documentation. Details are provided in section 5.4 of this manual.

#### 2.1.4 Treatment of Descriptors Not Fully Addressed By This Document

The goal for this document is to provide input and rating rules covering a full range of energy-related features encountered in commercial buildings. However, this goal is unlikely to ever be achieved due to the large number of features that must be covered and the continuous evolution of building materials and

technologies. For compliance and for Reach code, building features or systems not covered in this manual must apply for approval via the Exceptional Calculation method to the Commission. However, this manual may be amended with provisions to model additional features or HVAC systems during the code cycle. When this occurs, it is the responsibility of the software vendor to pass the necessary acceptance tests and apply for approval for the new building feature(s).

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## 2.2 Thermal Zones, HVAC Zones and Space Functions

### 2.2.1 Definitions

A *thermal zone* is a space or collection of spaces within a building having sufficiently similar space conditioning requirements so that those conditions could be maintained with a single thermal controlling device. A thermal zone is a thermal and not a geometric concept: spaces need not be contiguous to be combined within a single thermal zone. However, daylighting requirements may prevent combining non-contiguous spaces into a single thermal zone.

An *HVAC zone* is a physical space within the building that has its own thermostat and zonal system for maintaining thermal comfort. HVAC zones are identified on the HVAC plans. HVAC zones should not be split between thermal zones, but a thermal zone may include more than one HVAC zone.

A *space function* is a sub-component of a thermal zone that has specific standard design lighting requirements and for which there are associated defaults for outside air ventilation, occupancy, receptacle loads, and hot water consumption. An *HVAC zone* may contain more than one *space function*. Appendix 5.4A has a list of the space functions that may be used with the software. Daylighted areas should generally be defined as separate space functions, even if they have the same classification from Appendix 5.4A, so that lighting reductions due to daylighting can be determined at the appropriate resolution.

Figure 1 shows the hierarchy of *space functions*, *HVAC zones* and *thermal zones*.

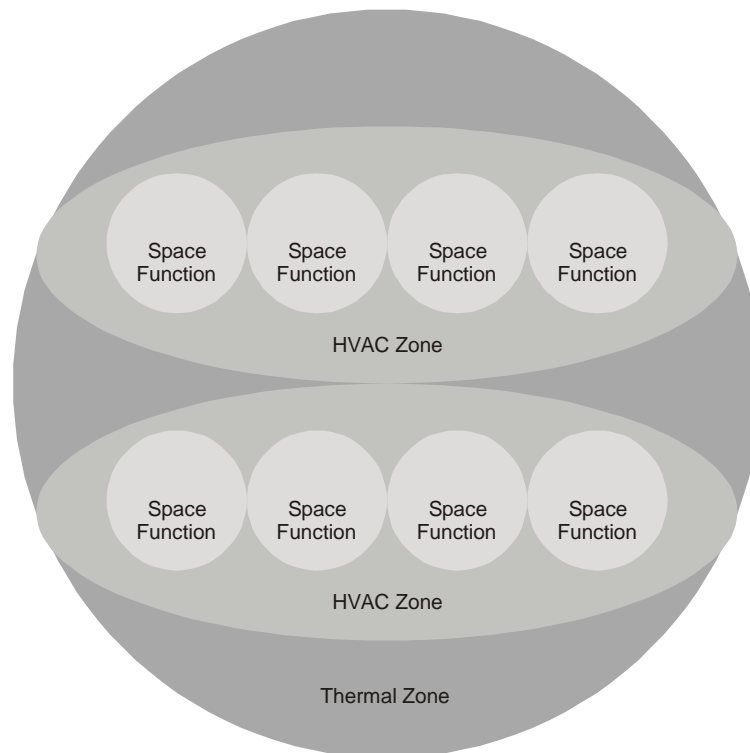


Figure 1 – Hierarchy of Space Functions, HVAC Zones and Thermal Zones

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## 2.3 Software Modeling Requirements for Zones

### 2.3.1 Required Zone Modeling Capabilities

For California compliance, software shall accept input for and be capable of modeling a minimum of fifty (50) thermal zones, each with its own control. Software shall also be capable of reporting the number of control points at the building level. When the number of control points is not greater than twenty (20) the compliance software shall have one HVAC zone per control point. Compliance software may use zone multipliers for identical zones. When the number of zones exceeds twenty (20), then (and only then) thermal zones may be combined subject to a variety of rules and restrictions.

### 2.3.2 Modeling Requirements for Unconditioned Spaces

Unconditioned space is enclosed space that is neither directly nor indirectly conditioned. Examples include stairways, warehouses, unoccupied adjacent tenant spaces, attached sunspaces, attics and crawl spaces.

Unconditioned spaces shall be modeled if they are part of the permitted space. All applicable envelope information shall be specified in a similar manner to conditioned space.

If unconditioned space is not a part of the permitted space, the space may be either explicitly modeled or its impact on the permitted space may be approximated by modeling the space as outdoor space and turning off solar gains to the demising wall that separates the permitted space from the adjacent unconditioned space. For unconditioned spaces that are explicitly modeled, all internal gains and operational loads (occupants, water heating, receptacle, lighting and process loads) shall be modeled as specified in Appendix 5.4A.

Return air plenums are considered indirectly conditioned spaces and shall be modeled as part of the adjacent conditioned space with equipment, lighting and occupant loads at zero.

Indirectly conditioned spaces can either be occupied or unoccupied. For spaces that are unoccupied, such as plenums, attics or crawlspaces, lighting, receptacle and occupant loads shall be zero. For spaces that can be occupied, such as stairwells or storage rooms, modeling assumptions shall be taken from Appendix 5.4A.

### 2.3.3 Space Use Classification Considerations

Thermal zones shall contain no more than ten different space use classifications, provided the spaces have similar space conditioning requirements. If the building area method is used, each thermal zone must be assigned to one and only one building area category. For space classifications that are combined in a single thermal zone, the spaces must meet all of the following conditions:

- Use the same HVAC operation schedule. Spaces that have a difference in full-load equivalent operating hours (FLEOH) of 40 or more shall not be combined.
- Use the same space temperature schedule.
- Have similar internal load power densities. Combined lighting, receptacle, and process equipment power densities that differ by no more than 2.0 W/ft<sup>2</sup> or a factor of two shall be considered similar.
- Have similar occupant densities. Occupant densities (i.e., densities represented in floor area per occupant [under peak design conditions]) that differ by no more than a factor of three shall be considered similar.
- A separate category shall exist for each change in efficiency standard level in the Appliance Efficiency Regulations and in §110.2.

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## 2.4 Unmet Load Hours

This manual uses the term “Unmet Load Hours” (UMLH) as a criterion for sizing equipment, for qualifying natural ventilation systems, and for other purposes. The concept of unmet load hours applies to individual thermal zones but is summed for hours whenever any thermal zone in the building has unmet loads. For a thermal zone, it represents the number of hours during a year when the HVAC system serving the thermal zone is unable to maintain the set point temperatures for heating and/or cooling. During periods of unmet loads, the space temperature drifts above the cooling setpoint or below the heating setpoint. A thermal zone is considered to have an unmet load hour if the space is outside the throttling range for heating or cooling. The throttling range is defined in Chapter 5 as the space temperature difference between no cooling and full cooling or between no heating and full heating. The throttling range is fixed at 2°F for simulating both the standard design and proposed design.

An unmet load hour occurs only during periods when the HVAC system is scheduled to operate. One hour with unmet loads in one or more thermal zones counts as a single unmet load hour for the building. If unmet load hours for more than one thermal zone coincide (occur at the same hour), they count as only one unmet load hour for the building. Therefore, the unmet load hours for the building will never be less than the worst thermal zone.

Unmet load hours can occur because fans, air flows, coils, furnaces, air conditioners or other equipment is undersized. Unmet load hours can also occur due to user errors including mismatches between the thermostat setpoint schedules and HVAC operating schedules or from other input errors, for instance, high internal gains or occupant loads. The term, as used in this manual, only addresses equipment that is undersized. It is the responsibility of the user to address other causes of unmet load hours in the proposed design.

## 2.5 Calculation Procedures

The general calculation procedure is illustrated in Figure 2. *The proposed design TDV energy use is compared to the standard design.*

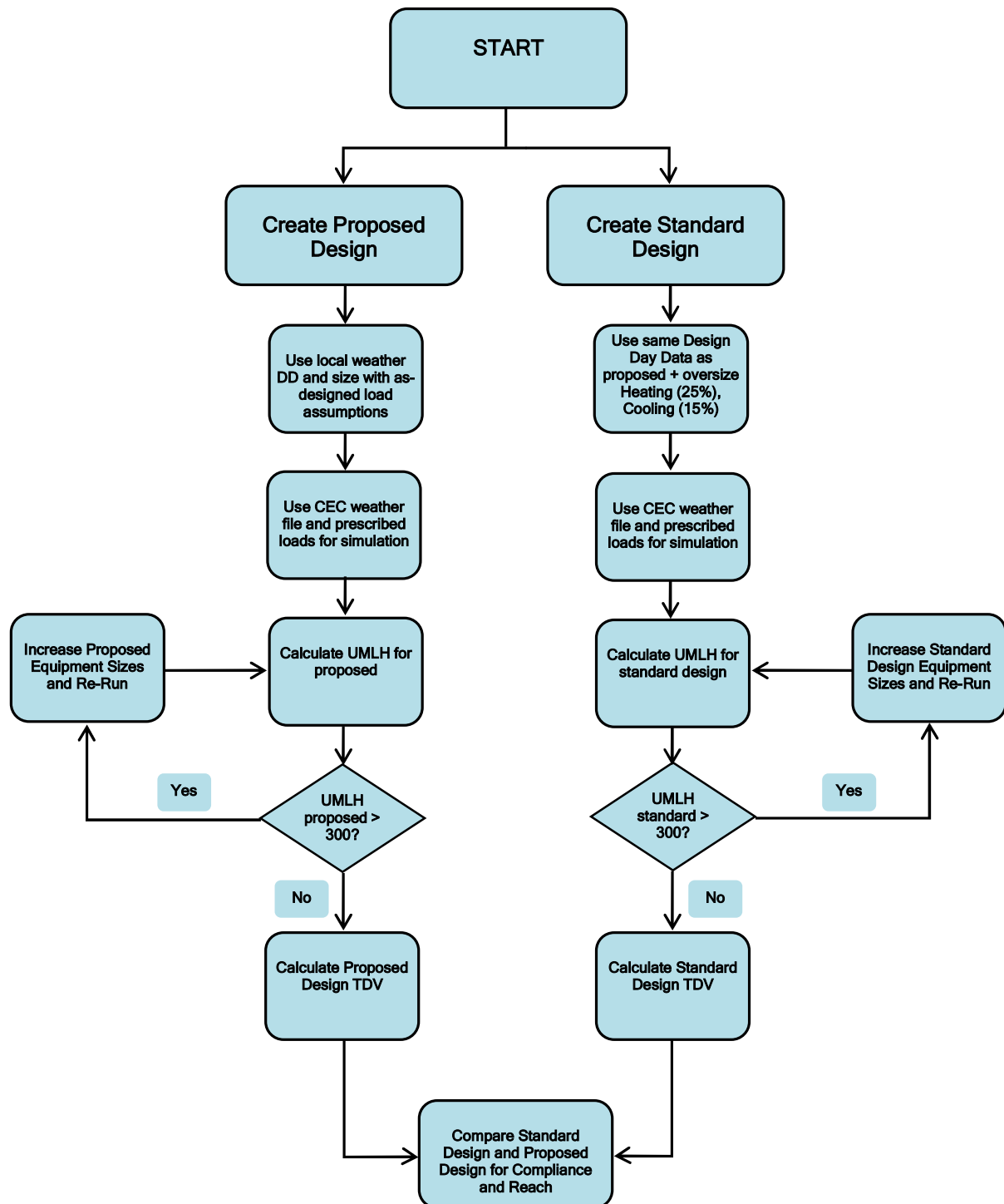


Figure 2 – Calculation Process for Title 24 Compliance and Reach

1. The process begins with a detailed description of the proposed design. Information is provided in enough detail to enable an estimate of annual energy use for a typical weather year. This information includes the building envelope, the lighting systems, the HVAC systems, the water heating systems and other important energy-using systems. This collection of information is referred to in this manual as *building descriptors*. Details on the building descriptors are provided in Chapter 5.
2. Before the calculations are performed, some of the building descriptors are modified for the proposed design to incorporate *prescribed* modeling assumptions. Prescribed modeling assumptions include occupant density, equipment power density, ventilation rates and water heating loads.
3. The next step is to make a simulation of the *proposed design* to determine how well the heating and cooling loads are being satisfied. The indicator is *unmet load hours*, the number of occupied hours during the year when the space temperature in one or more zones is below the heating set point temperature or greater than the cooling set point temperature. A large number of hours indicates that the equipment is undersized.
4. Test the number of unmet load hours and proceed only if the hours are less than or equal to 300 for the year of the proposed design simulation.
5. If the unmet load hours are greater than 300 for the year, then the proposed building simulation model is adjusted by the user to reduce the unmet load hours to less than or equal to 300. If the problem is heating, then the size of the boiler or furnace may need to be increased. If the problem is cooling, then the size of the coils or chillers may need to be increased. It is up to the designer to adjust equipment sizes as necessary; in some cases adjusting the zone airflows may solve the unmet load issue.
6. If the unmet load hours are less than or equal to 300, then the final simulation is performed. If no changes are made in the model, this may be the same simulation in step 3. These calculations produce the results that are compared to the standard design, which is calculated in steps 7 through 16.
7. Create the standard design following the rules in this manual. The standard design has the same floor area, number of floors and spatial configuration as the proposed design; however, systems and components are modified to be in minimum compliance with the *standard design*. The HVAC systems for the standard design are established according to rules in this manual and depend on the primary building activity (residential or non-residential), the floor area, and the number of stories. See Section 5.1.
8. Sizing calculations are performed for the standard design and heating equipment is oversized by 25% and cooling equipment by 15%.
9. The standard design is simulated to determine the number of unmet load hours. This process is the same as performed for the proposed design in step 3.
10. The number of unmet load hours for the standard design is then tested to see if they are greater than 300. This is not likely to occur since the heating and cooling equipment is oversized by 15% for cooling and 25% for heating in step 8.
11. If the unmet load hours are greater than 300, then equipment capacity in the standard design is increased so that the unmet hours are less than or equal to 300. See the discussion below on how equipment sizes are increased.
12. Once the tests on unmet load hours are satisfied, then the energy consumption of the standard design is calculated. If the tests on unmet hours are satisfied the first time through, this step is the same as step 9.
13. Finally, the proposed design TDV energy use and standard design TDV energy use are compared for compliance or Reach.

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## 2.6 HVAC Capacity Requirements and Sizing

To ensure that the simulated space-conditioning loads are adequately met, adequate capacity must be available in each of the components of the HVAC system; e.g., supply-air flow rates, cooling coils, chillers, and cooling towers. If any component of the system is incapable of adequate performance, the simulation may understate the required energy inputs for space conditioning and report unmet load hours. Adequate capacities are required in the simulations of both the proposed design and standard design. The subsections below describe the procedures that shall be followed to ensure that both versions of the design are simulated with adequate space-conditioning capacities.

### 2.6.1 Specifying HVAC Capacities for the Proposed Design

As shown in

Figure 2, the proposed design shall have no more than 300 unmet load hours. If this requirement is violated, the software shall require the user to make changes to the proposed design building description to bring the unmet load hours equal to or below 300. This process is not automated by the software.

There are two tests that must be met:

- Space loads must be satisfied: Space temperatures in all zones must be maintained within one half of the throttling range (1°F with a 2°F throttling range) of the scheduled heating or cooling thermostat setpoints. This criterion may be exceeded for no more than 300 hours for a typical year.
- System loads must be satisfied: Plant equipment must have adequate capacity to satisfy the HVAC system loads. This criterion may be exceeded for no more than 300 hours for a typical year.

If either the space or system loads do not meet the above criteria, the equipment in the proposed design shall be resized by the user such that the criteria are met. If the space conditioning criteria are not met because the HVAC equipment in the proposed design lacks the capability to provide either heating or cooling, equipment capable of providing the needed space conditioning must be modified by the user. The type of equipment added or modified will depend on the type of HVAC system in the proposed design and the judgment of the energy analyst.

Equipment sizes for the proposed design shall be entered into the model by the energy analyst and shall agree with the equipment sizes specified in the construction documents. When the simulations of these actual systems indicate that specified space conditions are not being adequately maintained in one or more thermal zone(s), the user shall be prompted to make changes to equipment sizes or zones as necessary. This occurs when the unmet load hours exceed 300 for the year. The use of equipment sizes that do not match the actual equipment sizes as indicated on construction documents triggers an Exceptional Condition that is noted on the compliance forms.

### 2.6.2 Sizing Equipment in the Standard Design

Equipment in the standard design is automatically oversized by the program (25% for heating and 15% for cooling). If the automatic oversizing percentage is not sufficient to meet demands, then Unmet load hours are evaluated at the building level by looking at the unmet load hours for each of the thermal zones being modeled. One hour with unmet loads in one or more thermal zones counts as a single unmet load hour for the building. Therefore, the unmet load hours for the building will never be less than the worst thermal zone.

If the number of total unmet load hours for cooling and/or heating exceeds 300, then equipment capacities of cooling and/or heating equipment must be increased by the software incrementally.

1. The first step is to determine whether heating or cooling unmet load hours are the bigger problem. If heating unmet load hours are the bigger problem, upsize the heating equipment capacity. If cooling UMLH is the problem, upsize the cooling equipment capacity.

2. If the cooling is undersized, the equipment is resized by first increasing the design airflow of all zones with significant unmet load hours (greater than 150 for an individual zone) by 10%, increasing the design airflow of all zones with some unmet load hours (between 50 and 150) by 5%. Then the equipment capacity for the system(s) serving the affected zones is increased to handle the increased zone loads. For central plant the chiller(s) or towers are resized proportionally to handle the increased system loads.

If heating is undersized, the same procedure is followed, with zones resized first, then heating secondary equipment and then boilers as necessary.

The capacity of the boiler or furnace shall be increased in 2% increments and the simulation re-run until the loads are met. For heat pumps the capacity of the coil is increased so that the additional load is not met by auxiliary heat.

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## 2.7 Ventilation Requirements

Design decisions regarding outside air ventilation shall be based on Section 120.1 of the Standards. If local codes do not apply, minimum values from Appendix 5.4A shall be used. Chapter 5.6 of the ACM has additional information on the ventilation requirements used in the building descriptors for the proposed and standard design. While no compliance credit can be claimed for reducing ventilation rates in the proposed design below the required levels, the user can specify higher ventilation rates in the proposed design.

## 3. Software Requirements

This chapter contains the software requirements for candidate Title 24 software that must be verified by acceptance testing. The tests fall into the following categories:

- Tests to verify that the software is evaluating thermal loads and the response of the HVAC systems to these loads in a manner that is acceptable. These tests reference *ASHRAE Standard 140-2007, Standard Method of Test for Evaluation of Building Energy Analysis Computer Programs*.
- Tests that verify that compliance software is capable of modeling envelope, lighting, HVAC and water heating efficiency features and provides precise estimates of energy tradeoffs and reasonably accurate predictions of building energy consumption.
- Tests to verify that the baseline building is created correctly, e.g. that the baseline HVAC system is properly specified, that other components of the baseline are correctly defined and that rules that fix and restrict inputs (such as schedules and plug loads) are properly applied.

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### 3.1 General Requirements

#### 3.1.1 Scope

The *Compliance Software* must satisfy the requirements contained in this section.

The *Compliance Software* shall be capable of modeling at least 50 *thermal zones*.

The *Compliance Software* shall be capable of modeling at least 15 separate HVAC systems.

#### 3.1.2 Calculation Methods

The *Compliance Software* shall calculate the annual consumption of all end uses in buildings, including fuel and electricity for:

- HVAC (heating, cooling, fans, and ventilation);
- Lighting (both interior and exterior);
- Receptacles and miscellaneous electric;
- Service water heating;
- Process energy uses;
- Commercial refrigeration systems; and
- All other energy end uses that typically pass through the building meter.

The *Compliance Software* shall perform a simulation on an hourly time interval (at a minimum) over a one year period (8760 hours) with the ability to model changes in weather parameters, schedules, and other parameters for each hour of the year. This is achieved by specifying a 24-hour schedule for each day of the week plus holidays.

### **3.1.2.1 Calculating Design Loads**

The software shall be capable of performing design load calculations for determining required HVAC equipment capacities and air and water flow rates using accepted industry calculation methods for the standard design.

### **3.1.2.2 Checking Simulation Output for Unmet Loads**

The software shall be capable of checking the output of the energy analysis module for the proposed design to ensure that space conditions are maintained within the tolerances specified (maximum of 300 unmet load hours per year).

### **3.1.2.3 Adjusting Capacities**

For the baseline building, the software shall be capable of modifying capacities, temperatures or flow rates for baseline building HVAC system components causing excessive unmet loads hours according to the procedures in Chapter 2.

### **3.1.2.4 Error Handling**

The software shall identify error conditions when unmet loads exceed 300 hours, prevent completion of the compliance analysis, and provide information to the user describing the error that has occurred and what steps the user should take to remedy the situation.

## **3.1.3 Climate Data**

The *Compliance Software* shall perform simulations using the official California Energy Commission weather files and design conditions documented in Joint Appendix 2.

The *Compliance Software* shall calculate solar radiation on exterior surfaces on an hourly basis from the values of direct normal irradiance and diffuse horizontal irradiance contained in the climate data, taking ground reflectance into account.

## **3.1.5 Time Dependent Valued (TDV) Energy**

The Compliance Software shall be capable of applying the Energy Commission TDV multipliers for each hour of the simulation. See California Joint Appendix 3.

## **3.1.6 Thermal Mass**

The calculation procedures used in the *Compliance Software* shall account for the effect of thermal mass on: loads due to occupants, lights, solar radiation, and transmission through building envelope; amount of heating and cooling required to maintain the specified space temperature schedules; and variation in space temperature.

## **3.1.7 Modeling Space Temperature**

The *Compliance Software* shall incorporate a dynamic simulation of space temperature which accounts for:

- Dynamics in change in heating and cooling setpoint temperatures;

- Deadband between heating and cooling thermostat settings;
- Temperature drift in transition to setback or setup thermostat schedules;
- Temperature drift in periods when heating or cooling capability are scheduled off;
- Temperature drift when heating or cooling capability of the system is limited by heating or cooling capacity, air flow rate, or scheduled supply air temperature; and
- Indirectly conditioned *thermal zones*, where the temperature is determined by internal loads, heat transfer through building envelope, and heat transfer between *thermal zones*.

### 3.1.8 Heat Transfer between Thermal zones

The *Compliance Software* shall be capable of modeling heat transfer between a *thermal zone* and adjacent *thermal zones*.

The *Compliance Software* shall account for the effect of this heat transfer on the space temperature, space conditioning loads, and resulting energy use in the *thermal zone* and in the adjacent *thermal zones*.

### 3.1.9 Control and Operating Schedules

The *Compliance Software* shall be capable of modeling control and operating schedules which can vary by:

- The hour of the day;
- The day of the week; and
- Holidays treated as a special day of the week.

The *Compliance Software* shall be capable of explicitly modeling all of the schedules specified in Appendix 5.4B of this manual.

### 3.1.10 Loads Calculation

The loads calculations described in this section relate to the simulation engine and not to the procedure used the design engineer to size and select equipment.

#### 3.1.10.1 Internal Loads

The *Compliance Software* shall be capable of calculating the hourly cooling loads due to occupants, lights, receptacles, and process loads.

The calculation of internal loads shall account for the dynamic effects of thermal mass.

The *Compliance Software* shall be capable of simulating schedules for internal loads in the form given in Appendix 5.4B.

The simulation of cooling load due to lights shall account for:

- The effect of the proportion radiant and convective heat, which depends on the type of light, on the dynamic response characteristic; and
- A portion of heat from lights going directly to return air, the amount depending on the type and location of fixture.

### **3.1.10.2 Building Envelope Loads**

The *Compliance Software* shall calculate heat transfer through walls, roofs and floors for each *thermal zone*, accounting for the dynamic response due to thermal characteristics of the particular construction as defined in the *Building Descriptors* in Chapter 5.

The calculation of heat transfer through walls and roofs shall account for the effect of solar radiation absorbed on the exterior surface, which depends on orientation and absorptance of the surface.

The *Compliance Software* shall calculate heat transfer through windows and skylights, accounting for both temperature difference and transmission of solar radiation through the glazing.

Calculation of cooling load due to transmission of solar radiation through windows and skylights shall account for:

- The angular incidence of the direct beam sunlight and the angular and spectral dependence of the solar properties.
- The variation of thermal properties of the fenestration system with ambient temperature.
- Orientation (azimuth and tilt of surface).
- The effect of shading from overhangs side fins, louvers or neighboring buildings or terrain.

### **3.1.10.3 Infiltration**

The *Compliance Software* shall be capable of simulating infiltration that varies by the time of day and day of the week. Schedules are provided in Appendix 5.4B.

### **3.1.10.4 Natural Ventilation**

The *Compliance Software* shall be capable of simulating natural ventilation.

## **3.1.11 Systems Simulation**

### **3.1.11.1 General**

The *Compliance Software* shall be capable of modeling:

- The baseline building systems defined in Chapter 5,
- The lighting, water heating, HVAC and miscellaneous equipment detailed in Chapter 5
- All compulsory and required features as detailed in Chapter 5

The capability to model multiple zone systems shall allow at least 15 *thermal zones* to be served by one multiple zone system.

The *Compliance Software* shall be capable of modeling plenum air return.

### **3.1.11.2 HVAC Zone Level Systems**

The *Compliance Software* shall be capable of simulating the effect on space temperature and energy use of:

- Limited capacity of terminal heating devices;
- Limited capacity of terminal cooling devices; and
- Limited rate of air flow to *thermal zones*.

### **3.1.11.3 HVAC Secondary Systems and Equipment**

The *Compliance Software* shall be capable of simulating the effect on energy use and space temperature in *thermal zones* served by the HVAC system of:

- Limited heating capacity of an HVAC system; and
- Limited cooling capacity of an HVAC system.

The simulation of HVAC systems shall account for:

- Temperature rise of supply air due to heat from supply fan, depending on the location of the fan;
- Temperature rise of return air due to heat from return fan;
- Temperature rise of return air due to heat from lights to return air stream; and
- Fan power as a function of supply air flow in variable air volume systems.

### **3.1.11.4 HVAC Primary Systems and Equipment**

The *Compliance Software* shall be capable of simulating the effect on energy use of limited heating or cooling capacity of the central plant system.

If the *Compliance Software* is not capable of simulating the effect of limited heating or cooling capacity of the central plant system on space temperature in *thermal zones* dependent on the central plant system for heating and cooling, then it shall issue a warning message when loads on the central plant system are not met.

### **3.1.11.5 Equipment Performance Curves**

The *Compliance Software* shall be capable of modeling the part load efficiency and variation in capacity of equipment as follows:

- Furnaces as a function of part load;
- Boilers as a function of part load, supply hot water temperature, and return hot water temperature;
- Water-cooled compressors including heat pumps and chillers as a function of part load, evaporator fluid, or air temperature and condensing fluid temperature;
- Air-cooled compressors including heat pumps, direct expansion cooling and chillers as a function of part load, ambient dry-bulb temperature, and wet-bulb temperature returning to the cooling coil;
- Evaporative cooling systems as a function of ambient wet-bulb temperature; and
- Cooling towers as a function of range and ambient wet-bulb temperature.

### **3.1.11.6 Economizer Control**

The *Compliance Software* shall be capable of modeling integrated air- and water-side economizers.

### **3.1.11.7 Air Side Heat-Recovery**

The *Compliance Software* shall be capable of modeling heat recovery between the exhaust air stream and the outside air stream. The software shall account for auxiliary energy uses associated with heat recovery systems, including pumping energy, frost control, and system control.

### 3.1.11.8 Heat-Recovery Water Heating

The Compliance Software shall be capable of modeling heat recovery water heating from the following sources:

- Double bundled chiller;
- Refrigerant desuperheater as part of a packaged HVAC unit;
- Heat exchanger on the condenser water loop; and
- Heat-recovery water-to-water heat pump operating off of the condenser or chilled water loop.

### 3.1.11.9 Heat-Pump Water Heaters

The Compliance Software shall be capable of modeling heat-pump water heaters. The algorithm must allow the evaporator coil to be located in:

- Any thermal zone;
- Any plenum; and
- Outside air.

## 3.1.12 Managing User Input

This section addresses the processes of data entry and the validation of user input data that can be performed prior to and independent of the energy simulation.

### 3.1.12.1 Building Descriptor Inputs and Restrictions

Building descriptors are discussed in Chapter 5. There are three types of inputs as shown in Table 2: compulsory, required and unsanctioned. Compulsory inputs must always be specified by the user for any compliance run. Required inputs shall be supported by the Compliance Software but they may not be applicable for all compliance runs. Some software may still be certified for compliance if it doesn't support some of the inputs listed in this manual; however, the software will only be certified for a limited scope commensurate with its capabilities. Unsanctioned inputs are inputs that are not addressed in this manual; these are not discussed in Chapter 5.

All inputs shall conform to the input conditions and restrictions specified in Chapter 5. Four levels of restriction are specified for building descriptors. The most limiting restriction is a prescribed value. This is an input that must be used in all instances, with no variation. A critical default may be overridden, but when it is, the user must provide special documentation. A default is provided for convenience and may be overridden by the user with no special documentation. For many inputs there is no restriction. The relationship between input types and restrictions is shown in Table 2.

*Table 2 – Input Types and Restrictions*

Input Type	Prescribed	Critical Default	Default	No Restriction
Compulsory	n.a.	n.a.	n.a.	✓
Required	✓	✓	✓	✓
Unsanctioned	n.a.	n.a.	n.a.	✓

Restrictions apply to all required inputs. The software user interface shall: 1) clearly indicate when a building descriptor has an associated default, 2) indicate what the default value is, and 3) provide a convenient means for the user to over-ride the default. When critical default values are overridden, the software interface shall notify the user that documentation of the revised assumption is required.

No restrictions are specified for unsanctioned inputs. The use of unsanctioned inputs may require an Exceptional Calculation Procedure application be submitted for the building system or features.

Compliance Software may not provide default assumptions other than those specified in Chapter 5. However, the software may assist the user in describing the proposed design by displaying typical values for building descriptors, provided deliberate action by the user is necessary before a displayed value is used.

### **3.1.12.2 Data Validation**

#### *Compulsory Input Checks*

The software shall check to ensure that valid entries have been made for all compulsory building descriptors before the user is permitted to proceed with the next step in the compliance process. Appendix 5.0 and Chapter 5 specify the compulsory building descriptors. Examples of compulsory inputs are climate zone, floor area, and area category classification.

#### *Handling of Missing Inputs*

If a required input is missing or invalid, the software shall: 1) notify the user that the input is missing or invalid, 2) identify the input field(s) with missing or invalid data, and 3) prevent the user from moving to the next step of the compliance process. The software may provide additional information designed to help the user correct the deficiency.

#### *Validity Checks*

The software shall check all user inputs to ensure that the following conditions are met:

- *Simulation Tool Limits* Inputs do not exceed the minimums or maximums for the parameters permitted by the simulation engine.
- *Compliance Rule Limits* Inputs do not exceed minimums or maximums for the descriptors specified in Chapter 5 of this document.
- *Simulation Tool Discrete Options* Inputs correspond with valid discrete or list options for parameters available in the simulation engine.
- *Compliance Rule Discrete Options* Inputs correspond with valid discrete options provided for in Chapter 5.

#### *Handling Invalid Input*

When invalid data is entered, the software shall: 1) notify the user of the invalid input, 2) identify the nonconforming input field, and 3) prevent execution of the next step of the compliance run; i.e., generating the input description for the proposed design. The software may provide additional information designed to help the user correct the deficiency.

#### *Consistency Checks*

The consistency checks described above are intended to identify errors and oversights in user input and thereby help ensure that the building description is complete and interpretable by the energy analysis program. Examples of consistency checks include that window should not exceed the areas of wall in which they are contained and that the necessary plant equipment has actually been connected to the secondary HVAC systems. The software may include additional consistency checks as needed.

#### *Handling Inconsistent Input*

If the proposed design fails a consistency check, the software shall: 1) notify the user that an inconsistency exists, 2) identify the specific consistency check that has been failed, 3) identify the inconsistent input fields, if feasible, and 4) prevent execution of the next step of the compliance process;

i.e., generating the input description for the proposed design. The software may provide additional information designed to help the user correct the deficiency.

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## 3.2 Special Documentation and Reporting Requirements

(THIS INFORMATION COULD PROBABLY BE SUMMARIZED IN A TABLE – ALL BUILDING DESCRIPTORS OF TYPE “CRITICAL DEFAULT” REQUIRE DOCUMENTATION IF THE DEFAULT VALUE IS OVERRIDDEN. THE REPORTING REQUIREMENTS SHOWN HERE HAVE NOT BEEN FINALIZED, BUT ARE REPRESENTATIVE OF THE TYPE OF EXCEPTIONAL FEATURES THAT REQUIRE DOCUMENTATION.)

### 3.2.1 Building Envelope

#### 3.2.1.1 Roof Radiative Properties

The user shall enter three-year aged roof reflectance and emittance for roofs that have been certified by the Cool Roof Rating Council.

#### 3.2.1.2 Ground Reflectance

When specific design features are incorporated to increase or reduce reflectance for the purpose of enhancing daylighting, there can be variation between the proposed design and the standard design, when appropriately documented. In cases where the default value is overridden, the user is required to submit documentation identifying the test procedure that was used to establish the non-default values.

#### 3.2.1.3 Exterior Wall Surface Properties

The default value for emittance is 0.90. The default value for reflectance is 0.30. There is no default for roughness. The default values may be overridden only in cases when the lower reflectance can be documented by manufacturers' literature or tests.

### 3.2.2 Interior Lighting

#### 3.2.2.1 Regulated Interior Lighting Power

Complete lighting plans and space plans are required for the tailored method. Prescriptive compliance forms for the tailored method shall be developed and these shall be verified by the plans examiner.

With the tailored lighting method, the software shall make an entry in the special features section on the California compliance forms that the tailored lighting method has been used to determine the lighting power for this space and that all necessary prescriptive tailored lighting forms and worksheets documenting the lighting and its justification shall be provided as part of the compliance documentation and be approved independently.

#### 3.2.2.2 Indoor Lighting Power (see 5.4.4)

Compliance software shall print all applicable lighting forms and report the lighting energy use and the lighting level (Watts/ft<sup>2</sup>) for the entire project. Compliance software shall report “No Lighting Installed” for nonresidential spaces with no installed lighting. Compliance software shall report “Default Residential Lighting” for residential units of high rise residential buildings and hotel/motel guest rooms.

If the modeled Lighting Power Density (LPD) is different than the actual LPD calculated from the fixture schedule for the building, Compliance software shall model the larger of the two values for sizing the mechanical systems and for the compliance run. Compliance software shall report the larger value on PERF-1. Lighting levels schedules shall be adjusted by any lighting Control Credit Watts, if input by the user.

Lighting power is not modeled in unconditioned spaces that are modeled, but lighting in those spaces is required to meet the prescriptive requirements for regulated unconditioned spaces such as commercial and industrial storage spaces and parking garages. When these types of spaces are entered the compliance software must report in the Special Features section that these spaces must comply with the prescriptive requirements for such spaces.

### **3.2.2.3 Design Illumination Setpoint**

Spaces that have low design illuminance levels, below the ranges specified in Appendix 5.4A, shall provide documentation that show the design illuminance to be used as the daylight illumination setpoint.

### **3.2.2.4 Primary and Secondary Daylighted Area**

The default primary daylight area for sidelighting is a band near the window with a depth equal to the distance from the floor to the top of the window. The default secondary daylight area for sidelighting is a band beyond the primary daylighted area that extends a distance double the distance from the floor to the top of the window. Other daylight areas may be defined with appropriate documentation.

### **3.2.2.5 Light Heat Gain Distribution**

Values within the ranges of Table 8 may be used when following the rules in the 2009 ASHRAE HOF. Other values may be used when manufacturers' literature and/or testing data is available, and adequate documentation is provided to the California Energy Commission.

## **3.2.3 Exterior Lighting**

If the lighted façade area exceeds exterior wall area or if door linear footage exceeds 25% of building perimeter, the software shall produce a warning.

## **3.2.4 Infiltration Data**

When credit is taken for reductions in infiltration (see above), test results or research reports shall be provided that document and support the inputs used for the baseline building and the proposed design.

## **3.2.5 HVAC Exceptional Conditions**

### **3.2.5.1 Equipment Sizing**

When the any proposed equipment size for secondary equipment or central plant equipment does not match the equipment size listed on construction documents, an exceptional condition shall be reported on compliance forms.

### **3.2.5.2 Custom Occupant, Fan, Heating or Cooling Schedules**

Custom hourly schedules may be used with appropriate documentation from project schedules. The default schedules from Appendix 5.4B apply unless they are overridden. The user must ensure that the HVAC schedule operating hours serve all of the occupied spaces, and spaces should not be combined when their weekly occupancy varies by more than 40 full load equivalent operating hours (FLEOH).

### **3.2.5.3 Equipment Performance Curves**

(Is documentation required if non-default HVAC equipment performance curves are used? For example, COOL-CAP-FT, COOL-EIR-FT, etc.)

(Note documentation required if credits for fault detection and diagnostics and/or airflow testing are taken.)

For equipment with a capacity less than or equal to 135,000 Btu/h, but larger than 65,000 Btu/h, the user may not enter data on the temperature dependent equipment performance. However, the compliance software vendor may work with manufacturers to collect such data and build this data into the compliance software. The user may either select equipment for which the compliance software vendor has collected or use the defaults.

### **3.2.5.4 Natural Ventilation**

The air flow rate for the proposed design shall be determined using sound engineering methods and supporting documentation shall be provided.

### **3.2.5.5 Condenser Flow Type**

The default is fixed condenser flow for water-cooled condensers. If the variable-flow is selected, the software must indicate that supporting documentation is required on the output forms.

### **3.2.5.6 Evaporative Cooling Performance Curves**

User may input curves or use default curves. If defaults are overridden, the software must indicate that supporting documentation is required on the output forms.

### **3.2.5.7 Condenser Heat Recovery Effectiveness**

As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.

### **3.2.5.8 Boiler Heat Loss**

Default is 2% for electric boilers and heat-exchangers and 0% for fuel-fired boilers. If the user overrides the default, supporting documentation is required.

### **3.2.5.9 Boiler Minimum Unloading Ratio**

If the user does not use the default value the software must indicate that supporting documentation is required on the output forms.

### **3.2.5.10 Chiller Minimum Unloading Ratio**

. If the user does not employ the default values, supporting documentation is required.

### 3.2.5.11 Cooling Tower Setpoint Control

If the user does not use the default control, supporting documentation is required.

### 3.2.5.12 Exterior Lighting Control

Documentation should be provided for lighting controls other than standard and evidence should be provided to support the reduction in lighting power (PAF).

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## 3.3 ASHRAE Standard 140-2007 Tests

This method of testing is provided for analyzing and diagnosing building energy simulation software using software-to-software and software-to-quasi-analytical-solution comparisons. The methodology allows different building energy simulation programs, representing different degrees of modeling complexity, to be tested by comparing the predictions from other building energy programs to the simulation results provided by the Compliance Software in question.

Compliance software must pass ASHRAE 140-2007 tests, but these tests are not part of the Reference Method.

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## 3.4 Reference Method Tests

The previous suite of tests, based on ASHRAE Standard 140-2007, verifies that the simulation engine produces appropriate models of fundamental building physics and predicts interactions between system components. Each test requires a simulation to be run. The tests in this section are intended to verify that the software correctly constructs the proposed design and baseline buildings and correctly applies the proposed design input restrictions specified in Chapter 5 and Appendix 5.0. A set of quantitative tests verifies that the candidate compliance software can accurately predict energy tradeoffs bre

### 3.4.1 Compliance Margin Tests

This document details the eligibility requirements for an applicant simulation program for use as compliance software under the 2013 ACM. A series of **quantitative** tests called the Compliance Margin Tests shall be performed and results compared against predetermined Reference results to demonstrate that the applicant software is acceptable for use in code compliance. There are a total of 168 tests. All the test cases described in Section VII shall be performed and results summarized in the forms contained in Appendix A.

#### 3.4.1.1 Overview

The applicant software shall perform a suite of Compliance Margin Test Cases to demonstrate that their performance is acceptable for code compliance. The applicant software test results shall be compared against a base case called the Reference tests. The Reference Test case is the corresponding match of a particular test case simulated already on EnergyPlus (v.7.0) engine. The Reference Model results, as determined by the Commission, are tabulated in Appendix A.

The test cases will assess the applicant software's sensitivity to various inputs ranging from envelope thermal conductance to HVAC system performance. Each case tests the impact of the input component on building end use energy and annual TDV. The following seven input components will be tested through a series of \_ tests:

- Opaque envelope

- Glazing
- Lighting
- Daylighting
- Receptacle loads
- HVAC System Parameters

### 3.4.1.2 Reference Model

The Reference Method tests are performed on seven Prototype Models which are a subset of the DOE Prototype Building Models developed by PNNL for analysis of ASHRAE Standard 90.1. The Reference Models are EnergyPlus model input files of the DOE prototype models, modified to comply with the requirements of Title-24 2013. The Reference Models will be the reference baseline runs for the test cases. The applicant software shall replicate the seven building models using the same inputs as the Reference Models. The models so replicated will be the applicant baseline models for the test cases.

A summary of the Reference Models is provided in Appendix A. Detailed EnergyPlus input files of the Reference models are available from the California Energy Commission's Building Energy Efficiency Software Consortium webpage <http://www.energydataweb.com/consortium/PACdocsNR.aspx>.

Reference Models used for the test cases are:

- Small Office Building:

This is a single story building of area 5500 square feet with punched windows distributed evenly across all facades. There are five thermal zones in this building served by packaged air conditioning units. For further details refer Appendix A.

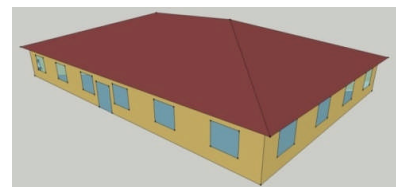


fig 1- Small Office

- Medium Office Building:

This Reference model is a three storied rectangular building with an overall area of 53600 square feet. It has a window to wall ratio of 33% with fenestration distributed evenly across all four facades. The zones are served by DX cooling and Gas furnace heating with electric reheat. For further details refer Appendix A.

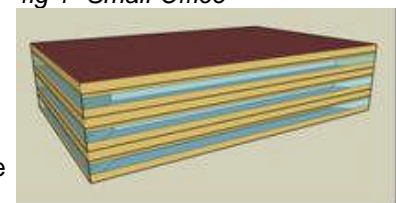


fig.2- Medium Office

- Large Office Building:

The large office building has twelve floors and a basement floor with glass windows with a window to wall ratio of 40% on the above-grade walls. The total area of the building is 498,600 square feet. The HVAC system type used is centrifugal chillers and gas boiler. For further details refer Appendix A.

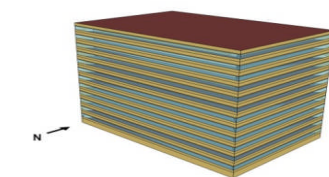


fig.3- Large Office

- Stand-Alone Retail:

The stand-alone retail is a single story rectangular building measuring 178 ft by 139 ft. The total area is 24695 square feet. Windows are located only on the street facing façade and occupy 25.4% of that façade. The building is divided into five thermal zones which are served by various system types as described in Appendix A.

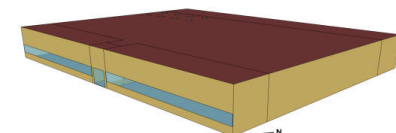


fig.4- Stand-Alone Retail

- Primary School:

The primary school building is a single story building with a total floor area of 73,960 square feet. It has a window to wall ratio of 35% with ribbon windows across all facades. Thermal zoning is as per exposure

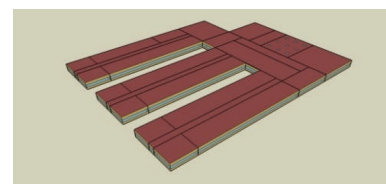


fig.5- Primary School

and space function. The zones are served by various system types. For further details refer Appendix A.

- Fast-food Restaurant:

The fast food restaurant Model has one floor of area 2500 square feet. Windows are located on the east, south and west sides of the dining zone façade. Window to wall ratio varies for each façade. The building is served by packaged air conditioning unit. For further details refer Appendix A.

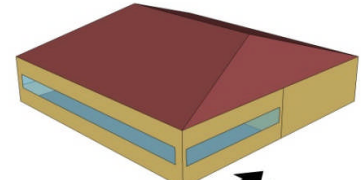


fig.6- Fast food Restaurant

- Warehouse Building:

The warehouse building has a total area of 49,495 square feet. It has three zones with office and storage spaces. The office spaces have punched windows. For further details refer Appendix A.

- Strip Mall Building:

The strip mall building has a total area of 22,500 square feet. It has ten zones each with rooftop units. The building has windows in the street facing façade and has an overall window to wall ratio of 10.5% . For further details refer Appendix A.

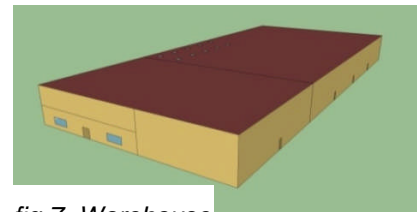


fig.7- Warehouse

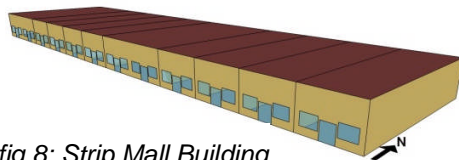


fig 8: Strip Mall Building

### 3.4.1.3 Climate Zones

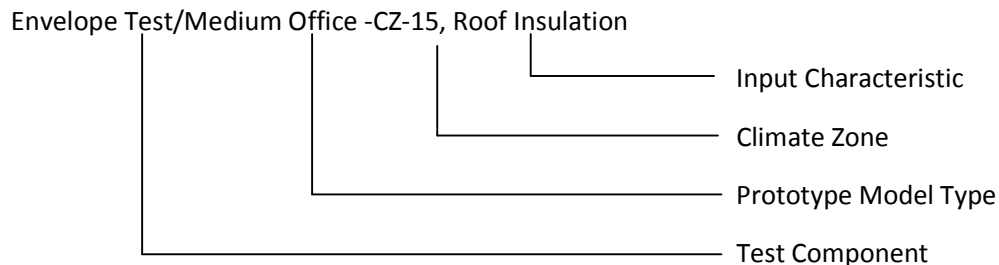
The Reference Method Test cases use five of the 16 California climate zones. Most tests are performed on two or three climate zones to capture the sensitivity of the input characteristic to extremes in weather conditions. The test cases are performed on climate zones 6, 15 and 16 which represent mild, hot and cold climates respectively. Daylighting tests are performed on climate zone 7 which has a high annual daylighting potential and climate zone 1, representative of climate with least annual daylighting potential.

Table 3-Climate Zones Tested

Climate Zone	Example City
1	Arcata
6	Long Beach
7	San Diego Lindbergh
15	Palm Springs-Intl
16	Blue Canyon

### 3.4.1.4 Labeling Computer Runs

Each test case used for the compliance test is labeled uniquely to make it easier to keep track of the runs and to facilitate analysis. The following scheme is used:



### 3.4.1.5 Test Criteria

Applicant software vendors shall perform a series of computer runs. Each of these runs shall be a systematic variation of the applicant base case model as described in Section VII. The applicant test case results will be compared to the reference results to verify that applicant software meets the requirements of the ACM. Simulation results for each test case will be compiled in forms provided in Appendix A. Compiled results will include annual site energy consumption for each end-use, overall site energy consumption, total unmet load hours and annual TDV and % variation of annual TDV and total end use site energy.

The annual TDV % variation shall be calculated using the formula:

$$TDV_{\%} = (TDV_b - TDV_n) / TDV_b$$

Where,  $TDV_{\%}$  is the TDV % variation,

$TDV_n$  is the annual TDV for test case number n and

$TDV_b$  is the annual TDV for the base case run.

In order to be accepted, the applicant software should fulfill the passing criteria as determined by the Commission:

For each test case,

When Reference Model  $TDV_{\%r} \leq 1\%$ , Allowed Maximum Applicant Model  $TDV_{\%a} = 1\%$

When Reference Model  $TDV_{\%r} > 1\%$ , Allowed Applicant Model  $TDV_{\%a}$  shall be within  $\pm 10\%$  of Reference Model  $TDV_{\%r}$

Where, the subscript "a" represents the applicant results and "r" represents the reference results.

If any of the tests fail to meet these criteria, the applicant software will not be accepted for compliance use.

### 3.4.1.6 Compliance Margin Test Cases

Test cases assess the energy impact of one or more of the building or system input characteristics on the baseline model. Each test suite consists of a series of unique test cases aimed to test the impact of a specific characteristic on building energy performance. Simulations are grouped according to test criteria and sub-grouped based on the reference model type to allow for direct comparison of results. For each test case, the applicant software will modify the applicant baseline model with specific inputs as described in the Test Case description section.

The test cases are simulated on multiple California weather files to evaluate the sensitivity of the building or system input to extremes in climate. Results of the test case runs and the TDV percent variation over the baseline run shall be compiled and compared against the reference results.

Each test case described in this section shall be compared against a baseline run. The baseline runs for each of the test cases are provided in Table 4 – Baseline Runs for Test Cases. A summary of the baseline reference Models is provided in [Appendix A](#). Detailed EnergyPlus input files of the Reference baseline and test case models are available from the California Energy Commission's, Building Energy Efficiency Software Consortium webpage <http://www.energydataweb.com/consortium/PACdocsNR.aspx>.

**Test cases:**

- **Envelope Test**

1. **Envelope Test/Medium Office-CZ-15, Roof Insulation-** This case tests the impact of modifying Roof assembly overall U value in climate zone 15. Roof assembly U value is increased 20% more than the baseline case.
2. **Envelope Test/Medium Office-CZ-15, Wall Insulation-** This case tests the impact of modifying Wall assembly overall U value in climate zone 15. Wall assembly U value is modeled 20% more than the baseline case.
3. **Envelope Test/Medium Office-CZ-15, Floor Slab Insulation-** This case tests the impact of a slab on grade floor with vertical perimeter insulation in climate zone 15. The baseline case has floor slab with no insulation.
4. **Envelope Test/Medium Office-CZ-15, Infiltration-** This case tests the impact of increasing the envelope infiltration by 5% compared to baseline case in climate zone 15.
5. **Envelope Test/Medium Office-CZ-16, Roof Insulation-** This case tests the impact of modifying Roof assembly overall U value in climate zone 16. Roof assembly U value is increased 20% more than the baseline case.
6. **Envelope Test/Medium Office-CZ-16, Wall Insulation-** This case tests the impact of modifying Wall assembly overall U value in climate zone 15. Wall assembly U value is modeled 20% more than the baseline case.
7. **Envelope Test/Medium Office-CZ-16, Floor Slab Insulation-** This case tests the impact of a slab on grade floor with vertical perimeter insulation in climate zone 15. The baseline case has floor slab with no insulation.
8. **Envelope Test/Medium Office-CZ-16, Infiltration-** This case tests the impact of increasing the envelope infiltration by 5% compared to baseline case in climate zone 16.
9. **Envelope Test/Medium Office-CZ-6, Roof Insulation-** This case tests the impact of modifying Roof assembly overall U value in climate zone 6. Roof assembly U value is increased 20% more than the baseline case.
10. **Envelope Test/Medium Office-CZ-6, Wall Insulation-** This case tests the impact of modifying Wall assembly overall U value in climate zone 6. Wall assembly U value is modeled 20% more than the baseline case.
11. **Envelope Test/Medium Office-CZ-6, Floor Slab Insulation-** This case tests the impact of a slab on grade floor with vertical perimeter insulation in climate zone 6. The baseline case has floor slab with no insulation.
12. **Envelope Test/Medium Office-CZ-6, Infiltration-** This case tests the impact of increasing the envelope infiltration by 5% compared to baseline case in climate zone 6.
13. **Envelope Test/Small Office-CZ-15, Low Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -15. Here, aged solar reflectance of the roofing product is increased by 20% compared to a low sloped base case roof.

14. **Envelope Test/Small Office-CZ-16, Low Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -16. Here, aged solar reflectance of the roofing product is increased by 20% compared to a low sloped base case roof.
15. **Envelope Test/Small Office-CZ-6, Low Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -6. Here, aged solar reflectance of the roofing product is increased by 20% compared to a low sloped base case roof.
16. **Envelope Test/Small Office-CZ-15, Steep Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -15. Here, aged solar reflectance of the roofing product is increased by 20% compared to a steep sloped base case roof.
17. **Envelope Test/Small Office-CZ-16, Steep Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -16. Here, aged solar reflectance of the roofing product is increased by 20% compared to a steep sloped base case roof.
18. **Envelope Test/Small Office-CZ-6, Steep Sloped Roof, Solar Reflectance-** This case tests the impact of modifying the reflectivity of the roof in climate zone -6. Here, aged solar reflectance of the roofing product is increased by 20% compared to a low sloped base case roof.
19. **Envelope Test/Primary School-CZ-15-Heavy Construction-** In this case, the impact of envelope mass on energy consumption in climate zone 15 is tested. The test case is modeled with a Solid concrete wall and compared against the light weight construction baseline.
20. **Envelope Test/Primary School-CZ-16-Heavy Construction-** In this case, the impact of envelope mass on energy consumption in climate zone 16 is tested. The test case is modeled with a Solid concrete wall and compared against the light weight construction baseline.
21. **Envelope Test/Primary School-CZ-6-Heavy Construction-** In this case, the impact of envelope mass on energy consumption in climate zone 6 is tested. The test case is modeled with a Solid concrete wall and compared against the light weight construction baseline.
- **Envelope Glazing Test**
22. **Envelope Glazing Test/Medium Office-CZ-15, Window U value-** This case tests the impact of reducing the window U value by 20% compared to baseline window U value on climate zone 15. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
23. **Envelope Glazing Test/Medium Office-CZ-15, Window SHGC value-** This case tests the impact of reducing the window SHGC value by 20% compared to baseline SHGC on climate zone 15. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
24. **Envelope Glazing Test/Medium Office-CZ-15, Window U & SHGC value-** This case tests the impact of reducing the window U and SHGC values by 20% compared to baseline on climate zone 15. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
25. **Envelope Glazing Test/Medium Office-CZ-16, Window U value-** This case tests the impact of reducing the window U value by 20% compared to baseline window U value on climate zone 16. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
26. **Envelope Glazing Test/Medium Office-CZ-16, Window SHGC value-** This case tests the impact of reducing the window SHGC value by 20% compared to baseline SHGC on climate zone 16. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.

- 27. Envelope Glazing Test/Medium Office-CZ-16, Window U & SHGC value-** This case tests the impact of reducing the window U and SHGC values by 20% compared to baseline on climate zone 16. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
- 28. Envelope Glazing Test/Medium Office-CZ-6, Window U value-** This case tests the impact of reducing the window U value by 20% compared to baseline window U value on climate zone 6. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
- 29. Envelope Glazing Test/Medium Office-CZ-6, Window SHGC value-** This case tests the impact of reducing the window U value by 20% compared to baseline window U value on climate zone 6. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
- 30. Envelope Glazing Test/Medium Office-CZ-6, Window U & SHGC value-** This case tests the impact of reducing the window U and SHGC values by 20% compared to baseline on climate zone 6. The intent is to test the sensitivity of the software to modifications in heat transmitted into the space through fenestration.
- 31. Envelope Glazing Test/Large Office-CZ-7, WWR of 20%-** In this case, the impact of reducing the window to wall ratio is tested. The test case is compared against the baseline which has a WWR of 40%. This case is tested for climate zone 7.
- 32. Envelope Glazing Test/Large Office-CZ-7, WWR of 60%-** In this case, the impact of increasing the window to wall ratio is tested. The test case is compared against the baseline which has a WWR of 40%. This case is tested for climate zone 7.
- 33. Envelope Glazing Test/Large Office-CZ-7, WWR of 60% with overhang on South Façade-** In this case, the impact of shading the south facing windows by a two feet deep overhang is tested. This case is tested for climate zone 7.
- 34. Envelope Glazing Test/Large Office-CZ-1, WWR of 20%-** In this case, the impact of reducing the window to wall ratio is tested. The test case is compared against the baseline which has a WWR of 40%. This case is tested for climate zone 1.
- 35. Envelope Glazing Test/Large Office-CZ-1, WWR of 60%-** In this case, the impact of increasing the window to wall ratio is tested. The test case is compared against the baseline which has a WWR of 40%. This case is tested for climate zone 1.
- **Lighting Test**
- 36. Lighting Test/Medium Office-CZ-15, low lighting power density-** This case tests the impact of reducing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 15.
- 37. Lighting Test/Medium Office-CZ-15, high lighting power density-** This case tests the impact of increasing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 15.
- 38. Lighting Test/Medium Office-CZ-16, low lighting power density-** This case tests the impact of reducing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 16.
- 39. Lighting Test/Medium Office-CZ-16, high lighting power density-** This case tests the impact of increasing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 16.
- 40. Lighting Test/Medium Office-CZ-6, low lighting power density-** This case tests the impact of reducing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 6.

- 41. Lighting Test/Medium Office-CZ-6, high lighting power density-** This case tests the impact of increasing the lighting power density of interior lights by 20% compared to baseline. This case is tested on climate zone 6.
- **Daylighting Test**
- 42. Daylighting Test/Large Office-CZ-7, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 40% and results compared against Large office Prototype model , both modeled for climate zone 7.
- 43. Daylighting Test/Large Office-CZ-7, Daylight sensors with Continuous Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 40%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model, both modeled for climate zone 7.
- 44. Daylighting Test/Large Office-CZ-7, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 40% and results compared against Large office Prototype model, both modeled for climate zone 7.
- 45. Daylighting Test/Large Office-CZ-7, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 40%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model, both modeled for climate zone 7.
- 46. Daylighting Test/Large Office-CZ-7,WWR of 20%, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 20% and results compared against Large office Prototype model , both modeled for climate zone 7.
- 47. Daylighting Test/Large Office-CZ-7, WWR of 20%, Daylight sensors with Continuous Dimming and windows with high VT--**This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 20%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 7.
- 48. Daylighting Test/Large Office-CZ-7, WWR of 20%, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 20% and results compared against Large office Prototype model in climate zone 7.
- 49. Daylighting Test/Large Office-CZ-7, WWR of 20%, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 20%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 7.
- 50. Daylighting Test/Large Office-CZ-7,WWR of 60%, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 60% and results compared against Large office Prototype model in climate zone 7.
- 51. Daylighting Test/Large Office-CZ-7, WWR of 60%, Daylight sensors with Continuous Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 60%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 7.

- 52. Daylighting Test/Large Office-CZ-7, WWR of 60%, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 60% and results compared against Large office Prototype model in climate zone 7.
- 53. Daylighting Test/Large Office-CZ-7, WWR of 60%, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 60%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 7.
- 54. Daylighting Test/Large Office-CZ-1, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 40% and results compared against Large office Prototype model, both modeled for climate zone 1.
- 55. Daylighting Test/Large Office-CZ-1, Daylight sensors with Continuous Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 40%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model, both modeled for climate zone 1.
- 56. Daylighting Test/Large Office-CZ-1, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 40% and results compared against Large office Prototype model, both modeled for climate zone 1.
- 57. Daylighting Test/Large Office-CZ-1, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 40%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model, both modeled for climate zone 1.
- 58. Daylighting Test/Large Office-CZ-1, WWR of 20%, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 20% and results compared against Large office Prototype model, both modeled for climate zone 1.
- 59. Daylighting Test/Large Office-CZ-1, WWR of 20%, Daylight sensors with Continuous Dimming and windows with high VT--** This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 20%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 1.
- 60. Daylighting Test/Large Office-CZ-1, WWR of 20%, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 20% and results compared against Large office Prototype model in climate zone 1.
- 61. Daylighting Test/Large Office-CZ-1, WWR of 20%, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 20%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 1.
- 62. Daylighting Test/Large Office-CZ-1, WWR of 60%, Daylight sensors with Continuous Dimming-** This case tests the impact of daylighting. Daylight sensors with continuous dimming is modeled in a large office building type with a WWR of 60% and results compared against Large office Prototype model in climate zone 1.

- 63. Daylighting Test/Large Office-CZ-1, WWR of 60%, Daylight sensors with Continuous Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with continuous dimming are modeled in a large office building type with a WWR of 60%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 1.
- 64. Daylighting Test/Large Office-CZ-1, WWR of 60%, Daylight sensors with Stepped Dimming-** This case tests the impact of daylighting. Daylight sensors with stepped dimming is modeled in a large office building type with a WWR of 60% and results compared against Large office Prototype model in climate zone 1.
- 65. Daylighting Test/Large Office-CZ-1, WWR of 60%, Daylight sensors with Stepped Dimming and windows with high VT-** This case tests the impact of daylighting. Daylight sensors with stepped dimming are modeled in a large office building type with a WWR of 60%. The visible transmittance of windows is increased to improve the daylighting potential. This case is tested on large office Prototype model in climate zone 1.
- 66. Daylighting Test/Stand Alone Retail-CZ-7, with skylights with high VT-** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the visible transmittance of the skylight glass. Standalone retail building in climate zone 7 is tested in this case.
- 67. Daylighting Test/Stand Alone Retail-CZ-7, with SRR of 5%-** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the SRR to 5% compared to baseline SRR of 1.3%. Standalone retail building in climate zone 7 is tested in this case.
- 68. Daylighting Test/Stand Alone Retail-CZ-7, with SRR of 5% and skylights with high VT -** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the SRR to 5% compared to baseline SRR of 1.3%, and visible transmittance of skylight glass. Standalone retail building in climate zone 7 is tested in this case.
- 69. Daylighting Test/Stand Alone Retail-CZ-1, with skylights with high VT--** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the visible transmittance of the skylight glass. Standalone retail building in climate zone 1 is tested in this case.
- 70. Daylighting Test/Stand Alone Retail-CZ-1, with SRR of 5%-%-** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the SRR to 5% compared to baseline SRR of 1.3%. Standalone retail building in climate zone 1 is tested in this case.
- 71. Daylighting Test/Stand Alone Retail-CZ-1, with SRR of 5% and skylights with high VT -** In this case the impact of daylighting with skylights is tested. Daylight potential is improved by increasing the SRR to 5% compared to baseline SRR of 1.3%, and visible transmittance of skylight glass. Standalone retail building in climate zone 1 is tested in this case.
- **Equipment Test**
- 72. Equipment Test/Medium Office-CZ-15, with low Equipment Power Density-** This case tests the impact of reducing the equipment power density by 20% compared to baseline. This case is tested on climate zone 15.
- 73. Equipment Test/Medium Office-CZ-15, with high Equipment Power Density-** This case tests the impact of increasing the equipment power density by 20% compared to baseline. This case is tested on climate zone 15.
- 74. Equipment Test/Medium Office-CZ-16, with low Equipment Power Density-** This case tests the impact of reducing the equipment power density by 20% compared to baseline. This case is tested on climate zone 16.

- 75. Equipment Test/Medium Office-CZ-16, with high Equipment Power Density-** This case tests the impact of increasing the equipment power density by 20% compared to baseline. This case is tested on climate zone 16.
- 76. Equipment Test/Medium Office-CZ-6, with low Equipment Power Density-** This case tests the impact of reducing the equipment power density by 20% compared to baseline. This case is tested on climate zone 6.
- 77. Equipment Test/Medium Office-CZ-6, with high Equipment Power Density-** This case tests the impact of increasing the equipment power density by 20% compared to baseline. This case is tested on climate zone 6.
- 78. Equipment Test/Fast food Restaurant-CZ-6, with high Process Load-** This case tests the impact of increasing the electric process load by 5% compared to baseline. This case is tested on climate zone 6.

The System test suit comprises of test cases for 12 different HVAC system types like:

- Packaged Terminal Air Conditioner
- Packaged Terminal Heat Pump
- Packaged Single Zone System
- Packaged VAV System
- Single duct built-up VAV system
- Fan coil units
- Water loop heat pump
- Evaporative cooling system
- Natural ventilation
- Hydronic radiant system
- Under-floor air distribution system
- Variable refrigerant flow (VRF) system

• **HVAC Test Cases**

- 79. HVAC Test /PTAC, Stripmall-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
- 80. HVAC Test /PTAC, Stripmall-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
- 81. HVAC Test /PTAC, Stripmall-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
- 82. HVAC Test /PTAC, Stripmall-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
- 83. HVAC Test /PTAC, Stripmall-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
- 84. HVAC Test /PTAC, Stripmall-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
- 85. HVAC Test /PTHP, Stripmall-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
- 86. HVAC Test /PTHP, Stripmall-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.

87. **HVAC Test /PTHP, Stripmall-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
88. **HVAC Test /PTHP, Stripmall-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
89. **HVAC Test /PTHP, Stripmall-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
90. **HVAC Test /PTHP, Stripmall-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
91. **HVAC Test/ PSZ, Stripmall-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
92. **HVAC Test/ PSZ, Stripmall-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
93. **HVAC Test/ PSZ, Stripmall-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
94. **HVAC Test/ PSZ, Stripmall-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
95. **HVAC Test/ PSZ, Stripmall-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
96. **HVAC Test/ PSZ, Stripmall-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
97. **HVAC Test/PVAV, Medium Office-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
98. **HVAC Test/PVAV, Medium Office-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
99. **HVAC Test/PVAV, Medium Office-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
100. **HVAC Test/PVAV, Medium Office-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
101. **HVAC Test/PVAV, Medium Office-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
102. **HVAC Test/PVAV, Medium Office-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
103. **HVAC Test /VAV, Large Office-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
104. **HVAC Test /VAV, Large Office-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.

105. **HVAC Test /VAV, Large Office-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
106. **HVAC Test /VAV, Large Office-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
107. **HVAC Test /VAV, Large Office-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
108. **HVAC Test /VAV, Large Office-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
109. **HVAC Test/FanCoil, Stripmall-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
110. **HVAC Test/FanCoil, Stripmall-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
111. **HVAC Test/FanCoil, Stripmall-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
112. **HVAC Test/FanCoil, Stripmall-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
113. **HVAC Test/FanCoil, Stripmall-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
114. **HVAC Test/FanCoil, Stripmall-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
115. **HVAC Test/VRF , Stripmall-CZ-6, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
116. **HVAC Test/VRF, Stripmall-CZ-6, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
117. **HVAC Test/VRF , Stripmall-CZ-15, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
118. **HVAC Test/VRF, Stripmall-CZ-15, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.
119. **HVAC Test/VRF , Stripmall-CZ-16, Low Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements lower than the 2008 Title 24 baseline.
120. **HVAC Test/VRF, Stripmall-CZ-16, High Efficiency-** This case tests the impact of modifying a set of parameters with efficiencies and requirements higher than the 2008 Title 24 baseline.

Table 4 – Baseline Runs for Test Cases

Test Case No.	Test Case	Baseline Model
1	Envelope Test Medium OfficeCZ-15 Roof Insulation	Medium Office CZ-15 Baseline
2	Envelope Test Medium OfficeCZ-15 Wall Insulation	
3	Envelope Test Medium OfficeCZ-15 Floor Slab Insulation	
4	Envelope Test Medium OfficeCZ-15 Infiltration	
5	Envelope Test Medium OfficeCZ-16 Roof Insulation	Medium Office CZ-16 Baseline
6	Envelope Test Medium OfficeCZ-16 Wall Insulation	
7	Envelope Test Medium OfficeCZ-16 Floor Slab Insulation	
8	Envelope Test Medium OfficeCZ-16 Infiltration	
9	Envelope Test Medium OfficeCZ-6 Roof Insulation	Medium Office CZ-6 Baseline
10	Envelope Test Medium OfficeCZ-6 Wall Insulation	
11	Envelope Test Medium OfficeCZ-6 Floor Slab Insulation	
12	Envelope Test Medium OfficeCZ-6 Infiltration	
13	Envelope Test Small OfficeCZ-15 SolarReflectance-Low Slope	Small Office CZ-15 SolarReflectance-Low Slope Baseline
14	Envelope Test Small OfficeCZ-16 SolarReflectance-Low Slope	Small Office CZ-16 SolarReflectance-Low Slope Baseline
15	Envelope Test Small OfficeCZ-6 SolarReflectance-Low Slope	Small Office CZ-6 SolarReflectance-Low Slope Baseline
16	Envelope Test Small OfficeCZ-15 SolarReflectance-Steep Slope	Small Office CZ-15 SolarReflectance-Steep Slope Baseline
17	Envelope Test Small OfficeCZ-16 SolarReflectance-Steep Slope	Small Office CZ-16 SolarReflectance-Steep Slope Baseline
18	Envelope Test Small OfficeCZ-6 SolarReflectance-Steep Slope	Small Office CZ-6 SolarReflectance-Steep Slope Baseline
19	Envelope Test Primary SchoolCZ-15 Heavy	Envelope Test Primary SchoolCZ-15 Light
20	Envelope Test Primary SchoolCZ-16 Heavy	Envelope Test Primary SchoolCZ-16 Light
21	Envelope Test Primary SchoolCZ-6 Heavy	Envelope Test Primary SchoolCZ-6 Light
22	Envelope Glazing Test Medium OfficeCZ-15 Window U	Medium Office CZ-15 Baseline
23	Envelope Glazing Test Medium OfficeCZ-15 Window SHGC	
24	Envelope Glazing Test Medium OfficeCZ-15 Window U&SHGC	
25	Envelope Glazing Test Medium OfficeCZ-16 Window U	Medium Office CZ-16 Baseline
26	Envelope Glazing Test Medium OfficeCZ-16 Window SHGC	
27	Envelope Glazing Test Medium OfficeCZ-16 Window U&SHGC	

28	Envelope Glazing Test Medium OfficeCZ-6 Window U	Medium Office CZ-6 Baseline
29	Envelope Glazing Test Medium OfficeCZ-6 Window SHGC	
30	Envelope Glazing Test Medium OfficeCZ-6 Window U&SHGC	
31	Envelope Glazing Test Large OfficeCZ-7 WWR 20%	Large Office CZ-7 Baseline
32	Envelope Glazing Test Large OfficeCZ-7 WWR 60%	
33	Envelope Glazing Test Large OfficeCZ-7 WWR 60% with South overhang	
34	Envelope Glazing Test Large OfficeCZ-1 WWR 20%	
35	Envelope Glazing Test Large OfficeCZ-1 WWR 60%	
36	Lighting Tests Medium OfficeCZ-15 low LPD	Medium Office CZ-15 Baseline
37	Lighting Tests Medium OfficeCZ-15 high LPD	
38	Lighting Tests Medium OfficeCZ-16 low LPD	Medium Office CZ-16 Baseline
39	Lighting Tests Medium OfficeCZ-16 high LPD	
40	Lighting Tests Medium OfficeCZ-6 low LPD	Medium Office CZ-6 Baseline
41	Lighting Tests Medium OfficeCZ-6 high LPD	
42	Daylighting Tests Large OfficeCZ-7 Continuous Dimming	Large Office CZ-7 Baseline
43	Daylighting Tests Large OfficeCZ-7 Continuous Dimming and high VT	
44	Daylighting Tests Large OfficeCZ-7 Stepped Dimming	
45	Daylighting Tests Large OfficeCZ-7 Stepped Dimming and high VT	
46	Daylighting Tests Large OfficeCZ-7 WWR-20%,Continuous Dimming	Large Office CZ-7 WWR 20% Baseline
47	Daylighting Tests Large OfficeCZ-7 WWR-20%,Continuous Dimming and high VT	
48	Daylighting Tests Large OfficeCZ-7 WWR-20%,Stepped Dimming	
49	Daylighting Tests Large OfficeCZ-7 WWR-20%,Stepped Dimming and high VT	
50	Daylighting Tests Large OfficeCZ-7WWR-60%,Continuous Dimming	Large Office CZ-7 WWR 60% Baseline
51	Daylighting Tests Large OfficeCZ-7 WWR-60%,Continuous Dimming and high VT	
52	Daylighting Tests Large OfficeCZ-7 WWR-60%,Stepped Dimming	
53	Daylighting Tests Large OfficeCZ-7 WWR-60%,Stepped Dimming and high VT	
54	Daylighting Tests Large OfficeCZ-1 Continuous Dimming	Large Office CZ-1 Baseline

55	Daylighting Tests Large OfficeCZ-1 Continuous Dimming and high VT	
56	Daylighting Tests Large OfficeCZ-1 Stepped Dimming	
57	Daylighting Tests Large OfficeCZ-1 Stepped Dimming and high VT	
58	Daylighting Tests Large OfficeCZ-1 WWR-20%,Continuous Dimming	<b>Large Office CZ-1 WWR-20% Baseline</b>
59	Daylighting Tests Large OfficeCZ-1 WWR-20%,Continuous Dimming and high VT	
60	Daylighting Tests Large OfficeCZ-1 WWR-20%,Stepped Dimming	
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72	Equipment test Medium OfficeCZ-15 low EPD	<b>Medium Office CZ-15 Baseline</b>
73	Equipment test Medium OfficeCZ-15 high EPD	
74	Equipment test Medium OfficeCZ-16 low EPD	<b>Medium Office CZ-16 Baseline</b>
75	Equipment test Medium OfficeCZ-16 high EPD	
76	Equipment test Medium OfficeCZ-6 low EPD	<b>Medium Office CZ-6 Baseline</b>
77	Equipment test Medium OfficeCZ-6 high EPD	
78	Equipment test Fast food RestaurantCZ-6 high Process load	<b>Fast food Restaurant CZ-6 Baseline</b>
79	PTAC Test Strip Mall CZ-6 Low Eff	<b>PTAC Strip Mall CZ-6 Baseline</b>
80	PTAC Test Strip Mall CZ-6 High Eff	
81	PTAC Test Strip Mall CZ-15 Low Eff	<b>PTAC Strip Mall CZ-15 Baseline</b>

82	PTAC Test Strip Mall CZ-15 High Eff	
83	PTAC Test Strip Mall CZ-16 Low Eff	<b>PTAC Strip Mall CZ-16 Baseline</b>
84	PTAC Test Strip Mall CZ-16 High Eff	
85	PTHP Test Strip Mall CZ-6 Low Eff	<b>PTHP Strip Mall CZ-6 Baseline</b>
86	PTHP Test Strip Mall CZ-6 High Eff	
87	PTHP Test Strip Mall CZ-15 Low Eff	<b>PTHP Strip Mall CZ-15 Baseline</b>
88	PTHP Test Strip Mall CZ-15 High Eff	
89	PTHP Test Strip Mall CZ-16 Low Eff	<b>PTHP Strip Mall CZ-16 Baseline</b>
90	PTHP Test Strip Mall CZ-16 High Eff	
91	PSZ Test Strip Mall CZ-6 Low Eff	<b>PSZ Strip Mall CZ-6 Baseline</b>
92	PSZ Test Strip Mall CZ-6 High Eff	
93	PSZ Test Strip Mall CZ-15 Low Eff	<b>PSZ Strip Mall CZ-15 Baseline</b>
94	PSZ Test Strip Mall CZ-15 High Eff	
95	PSZ Test Strip Mall CZ-16 Low Eff	<b>PSZ Strip Mall CZ-16 Baseline</b>
96	PSZ Test Strip Mall CZ-16 High Eff	
97	PVAV Test Medium Office CZ-6 Low Eff	<b>PVAV Medium Office CZ-6 Baseline</b>
98	PVAV Test Medium Office CZ-6 High Eff	
99	PVAV Test Medium Office CZ-15 Low Eff	<b>PVAV Medium Office CZ-15 Baseline</b>
100	PVAV Test Medium Office CZ-15 High Eff	
101	PVAV Test Medium Office CZ-16 Low Eff	<b>PVAV Medium Office CZ-16 Baseline</b>
102	PVAV Test Medium Office CZ-16 High Eff	
103	VAV Test Large Office CZ-6 Low Eff	<b>VAV Large Office CZ-6 Baseline</b>
104	VAV Test Large Office CZ-6 Low Eff	
105	VAV Test Large Office CZ-15 Low Eff	<b>VAV Large Office CZ-15 Baseline</b>
106	VAV Test LargeOffice CZ-15 Low Eff	
107	VAV Test LargeOffice CZ-16 Low Eff	<b>VAV Large Office CZ-16 Baseline</b>
108	VAV Test LargeOffice CZ-16 Low Eff	
109	FanCoil Test Strip Mall CZ-6 Low Eff	<b>FanCoil Strip Mall CZ-6 Baseline</b>
110	FanCoil Test Strip Mall CZ-6 High Eff	
111	FanCoil Test Strip Mall CZ-15 Low Eff	<b>FanCoil Strip Mall CZ-15 Baseline</b>
112	FanCoil Test Strip Mall CZ-15 High Eff	
113	FanCoil Test Strip Mall CZ-16 Low Eff	<b>FanCoil Strip Mall CZ-16 Baseline</b>
114	FanCoil Test Strip Mall CZ-16 High Eff	
115	VRF Test Strip Mall CZ-6 Low Eff	<b>PSZ Strip Mall CZ-6 Baseline</b>
116	VRF Test Strip Mall CZ-6 High Eff	
117	VRF Test Strip Mall CZ-15 Low Eff	<b>PSZ Strip Mall CZ-15 Baseline</b>
118	VRF Test Strip Mall CZ-15 High Eff	
119	VRF Test Strip Mall CZ-16 Low Eff	<b>PSZ Strip Mall CZ-16 Baseline</b>

120	VRF Test Strip Mall CZ-16 High Eff	

### 3.4.1.7 Results Documentation

The applicant shall perform simulations for all tests specified in Section VII and report results in the forms provided in Appendix A.

## 3.4.2 Ruleset Implementation Tests

The Compliance Margin Tests in the Reference Method suite of tests verifies that the simulation engine produces results that are within an acceptable range. The tests in this section are intended to verify that the software correctly constructs the baseline model and applies rules of the 2013 Nonresidential ACM appropriately to the proposed and baseline models. Evaluation of the modeling assumptions and baseline building tests is **qualitative**.

### 3.4.2.1 Overview

The test runs described in this section represent the Title-24 2013 Non-Residential ACM code compliance calculation and use the following Prototype Models- Small Office Building, Medium Office Building, Large Office Building, Warehouse Building and Small Hotel. For further details on the Prototype Models, refer to Section III of the Software Compliance Specification document. Each of the baseline test cases shall be created by modifying the Prototype Model as described in Section IV of this document. The modified Prototype Model shall form the proposed case for each test run. The baseline model shall be generated by compliance software as per the rules in the 2013 Nonresidential ACM. The baseline and proposed model files for each of test cases shall then be evaluated to verify that:

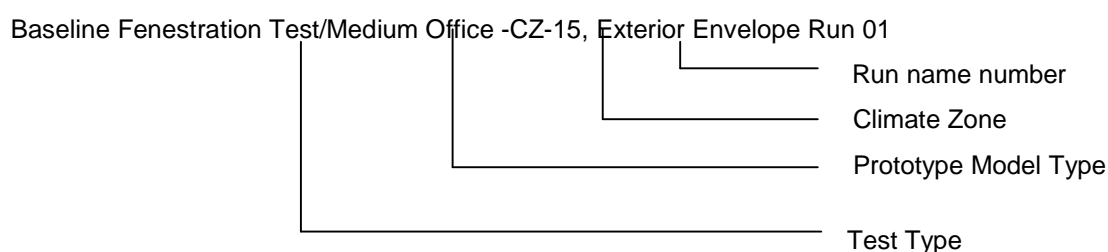
- The baseline building envelope constructions are correctly substituted for exterior opaque surfaces and fenestrations.
- Fenestration area in the baseline building is reduced in accordance with the 2013 Nonresidential ACM Manual, when the proposed design fenestration area is greater than 40% of the exterior wall.
- Skylight area in the baseline building is adjusted in accordance with the 2013 Nonresidential ACM Manual, when applicable.
- Default schedules of operation are applied for both the baseline building and the proposed design.
- The proposed and baseline cases use the same defaults or tailored inputs for internal loads as required by the 2013 Nonresidential ACM Manual.
- The baseline building lighting system is correctly specified and that exterior lighting is modeled.
- Receptacle loads, process loads is modeled according to the rules in the 2013 Nonresidential ACM Manual.
- The baseline building use the correct system types as prescribed in Table\_ of the 2013 Nonresidential ACM Manual.
- An economizer (of the right type) is included in the baseline building if required.
- The primary and secondary baseline building systems are properly specified and sized.
- Fan brake horsepower is correctly specified for the baseline building.
- Prescribed modeling assumptions are applied for both the baseline building and the proposed design.

- Overhangs are modeled in the proposed design for Run 7 but not the baseline building.
- Unconditioned spaces are modeled.
- Other baseline building specifications and/or modeling assumptions are correctly applied.

As the software developer verifies the above and other conditions, the input and output files should be annotated with comments or other methods to demonstrate that the modeling rules specified in the 2013 Nonresidential ACM Manual are correctly applied. Software developers should use the output format spreadsheets, included in Appendix B, to report the results of these tests. These annotated files shall then be submitted to the Commission for further evaluation. Any errors discovered shall be corrected by making modifications to the software; the runs shall be repeated; and the new results shall be annotated for submittal to the Commission.

### 3.4.2.2 Labeling of Baseline Tests

The Baseline Tests are labeled using the format:



### 3.4.2.3 Rule set Implementation Tests

The following tests shall be performed to verify that the compliance software correctly creates the baseline model and applies modeling rules as per the requirements of the Nonresidential ACM 2013. The proposed model shall be created by modifying the appropriate Prototype Model type. The Baseline Model for each test case shall be generated automatically by the compliance software.

The intent of each test run, characteristics of the proposed model and inputs to be verified in the baseline model are described below.

1. Baseline Exterior Envelope Test/Small Office-CZ-6, Run01– This test will verify that the applicant software models the wall, floor and roof construction correctly in the baseline model and the envelope and fenestration performance requirements for the baseline are modelled as per the requirements of NACM 2013.

The proposed model is a small office building in climate zone 6 with the following envelope characteristics-

- Low sloped concrete roof with assembly U value of 0.065, Aged Solar Reflectance of 0.75 and Thermal emittance of 0.78.
- Wood-framed wall with assembly U value of 0.090
- Mass floor with assembly U value of 0.15.
- Fixed window with U factor of 0.25, RSHGC of 0.20 and V.T of 0.45.

The following inputs in the baseline model file shall be verified and reported in the output form provided in Appendix B-

- Baseline roof, wall and floor construction assembly type
- Baseline roof, wall and floor overall U-value
- Baseline roof, wall and floor construction assembly layer inputs
- Baseline roof aged solar reflectance and thermal emittance.
- Window U value, SHGC and V.T

2. Baseline Exterior Envelope Test/Small Office-CZ-15, Run02 – This test will verify that the applicant software models the wall, floor, roof construction and fenestrations correctly and the envelope performance requirements for the baseline are modelled as per the NACM 2013. The proposed model is a small office building in climate zone 15 with the following envelope characteristics-
  - Steep sloped metal building roof with assembly U value of 0.055, Aged Solar Reflectance of 0.60 and Thermal emittance of 0.70.
  - Metal- framed wall with assembly U value of 0.056
  - Slab on grade floor with floor F factor of 0.70.
  - Horizontal overhang of 2 feet on south facing windows and vertical fins of 2 feet on right and left of west facing windows.

The following inputs in the baseline model file shall be verified and reported in the output form-

  - Baseline roof, wall and floor construction assembly type
  - Baseline roof, wall and floor construction assembly layer inputs
  - Baseline roof, wall overall U-value
  - Baseline floor slab F-factor.
  - Baseline roof aged solar reflectance and thermal emittance.
  - Window overhangs for south and west windows.
3. Baseline Exterior Envelope Test/Small Hotel-CZ-15, Run03 – This test will verify that the applicant software models the wall, floor and roof construction correctly in the baseline model and the envelope and fenestration performance requirements for the baseline are modelled as per the requirements of NACM 2013. The proposed model is a small hotel building in climate zone 15 with the following characteristics-
  - Low sloped Metal building Roof with assembly U value of 0.055, Aged Solar Reflectance of 0.60 and Thermal emittance of 0.70
  - Metal- framed wall with assembly U value of 0.8
  - Mass Floor with assembly U value of 0.052.
  - Fixed windows in the first floor with U factor of 0.25, RSHGC of 0.20 and V.T of 0.47.
  - Operable windows in guest room windows with U factor of 0.42, RSHGC of 0.18 and V.T of 0.35.

The following inputs in the baseline model file shall be verified and reported in the output form-

  - Baseline roof, wall and floor construction assembly type
  - Baseline roof, wall and floor construction assembly layer inputs
  - Baseline roof, wall and floor U-value
  - Baseline roof aged solar reflectance and thermal emittance.
  - Window U value, SHGC and V.T
4. Baseline Fenestration Test/Large Office-CZ-6, WWR Run04 - Run 04 tests whether the applicant software determines the window area of the baseline model as per the rules in NACM 2013. The proposed model is the Large office building in climate zone six with an overall window to wall ratio (WWR) of 60% made of a continuous band of glass distributed evenly across all facades. For this run, the building is rotated 15 degrees to the east in azimuth.
 

The following inputs in the baseline model file shall be verified and reported in the output form-

  - Baseline WWR
5. Baseline Fenestration Test/Large Office-CZ-6, WWR Run05 - Run 05 tests whether the applicant software determines the window area of the baseline model as per the rules in NACM 2013. The proposed model is the Large office building in climate zone six with overall building WWR- 30% and 45% WWR in the western façade.
 

The following inputs in the baseline model file shall be verified and reported in the output form-

- Baseline WWR
6. Baseline Fenestration Test/Large Office-CZ-6, WWR Run06 - Run 06 tests whether the applicant software determines the window area of the baseline model as per the rules in NACM 2013. The proposed model is the Large office building in climate zone six with overall building WWR- 46% and 50% WWR in the west, 40% in South, 45% in East and 50% in the North façade.  
The following inputs in the baseline model file shall be verified and reported in the output form-
    - Baseline WWR
  7. Baseline Skylight Test/Warehouse-CZ-6, Run07 – This tests verifies whether the applicant software models the baseline skylight as per the performance requirements for skylights in NACM 2013.  
The proposed model is a Warehouse building in climate zone six with the following characteristics-
    - Curb mounted glass Skylight with U value 0.55 ,SHGC 0.20 and V.T 0.40.
 The following inputs in the baseline model file shall be verified and reported in the output form-
    - Skylight U value, SHGC and VT.
  8. Baseline Skylight Test/Warehouse-CZ-6, SRR Run08 – This test checks whether the applicant software determines the skylight area of the baseline model correctly. The proposed model is a Warehouse building in climate zone 6 with an overall Skylight to roof ratio (SRR) of 7%.  
The following inputs in the baseline model file shall be verified and reported in the output form-
    - Baseline SRR.
  9. Baseline Skylight Test/Warehouse-CZ-6, SRR Run09- This test checks whether the applicant software determines the skylight area of the baseline model correctly. The proposed model is a Warehouse building in climate zone 6. The SRR of the proposed building is 15% and more than 75% of the building area gets daylighting from skylights or sidelights .  
The following baseline inputs shall be verified:
    - Baseline SRR, baseline total daylit area as a fraction of gross building area.
  10. Baseline Skylight Test/Warehouse-CZ-6, SRR Run10- This test checks whether the applicant software determines the skylight area of the baseline model correctly. The proposed model is a Warehouse building in climate zone 6. The SRR of the proposed building is 5% and 55% of the building area gets daylighting from skylights or sidelights .  
The following baseline inputs shall be verified:
    - Baseline SRR, baseline total daylit area as a fraction of gross building area.
  11. Baseline Occupancy Test/Medium Office-CZ-6, Whole Building Method Run11- This test verifies whether the applicant software inserts the correct baseline inputs for schedules, occupant density, equipment power density, lighting power density, hot water load and ventilation rates using the whole building method and in accordance with NACM 2013. The proposed model is an office occupancy with:
    - Occupant Density- 100 ft<sup>2</sup>/person
    - Equipment Power Density- 1.34 W/ft<sup>2</sup>
    - Lighting Power Density- 1.2 W/ft<sup>2</sup>
    - Hot Water Load- 106 Btu/person
    - Ventilation Rate- 0.15 cfm/ft<sup>2</sup>
 The baseline model inputs shall be verified for-
    - Schedules (verified shall include occupancy schedule, lighting schedule, receptacle schedule, hot water schedule, infiltration schedule and elevator schedule)
    - Occupant Density
    - Equipment Power Density
    - Lighting Power Density
    - Hot Water Load

- Ventilation Rate
12. Baseline Occupancy Test/Large Office- CZ-6, Space by Space Method Run12- This test verifies whether the applicant software inserts the correct baseline inputs for schedules, occupant density, equipment power density, lighting power density, hot water load and ventilation rates in accordance with NACM 2013. This run tests the capability of the applicant software to model baseline inputs for multiple space types using the Space by Space method. The proposed model is the Large office building in climate zone six with the following characteristics-
    - First Floor- Retail space occupancy- Occupant Density 30 ft<sup>2</sup>/person, EPD-1W/ft<sup>2</sup>, LPD-1W/ft<sup>2</sup>, Ventilation rate- 0.25 cfm/ft<sup>2</sup>, Hot Water Load- 120 Btuh/person.
    - Second Floor- Medical occupancy- Occupant Density 100 ft<sup>2</sup>/person, EPD-1.5 W/ft<sup>2</sup>, LPD-1W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>, Hot Water Load- 160 Btuh/person.
    - Third to 12th Floor North, South, West and East zones -Offices occupancy- Occupant Density 150 ft<sup>2</sup>/person, EPD-1.5 W/ft<sup>2</sup>, LPD-0.75 W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>, Hot Water Load- 120 Btuh/person.
    - Third and Fifth Floor Core zones- Lobby occupancy- Occupant Density 100 ft<sup>2</sup>/person, EPD-0.5 W/ft<sup>2</sup>, LPD-1.5 W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>.
    - Fourth, Seventh, 10<sup>th</sup> and 12<sup>th</sup> Floor Core Zones- Conference occupancy- Occupant Density 100 ft<sup>2</sup>/person, EPD-1.0 W/ft<sup>2</sup>, LPD-1.2 W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>, Hot Water Load- 60 Btuh/person.
    - Sixth, Eighth Floor Core Zone- Restroom occupancy- Occupant Density 100 ft<sup>2</sup>/person, EPD-0.2 W/ft<sup>2</sup>, LPD-0.5 W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>.
    - Ninth and 11<sup>th</sup> Floor Core Zones- Corridor occupancy- Occupant Density 100 ft<sup>2</sup>/person, EPD-0.2 W/ft<sup>2</sup>, LPD-0.5 W/ft<sup>2</sup>, Ventilation rate- 0.15 cfm/ft<sup>2</sup>.
  13. Baseline Tailored Lighting Method/Medium Office-CZ-6, Run13- This test verifies if the applicant software applies the trade-off requirements of the Tailored Lighting Method appropriately. Proposed Model is a medium office building in climate Zone 6 with the following characteristics-
    - Perimeter zones on all floors are modelled as main entry spaces using the Tailored Lighting Method. The space has a general lighting of 0.5 W/ft<sup>2</sup>.
    - Core zones on all floors are modelled as waiting spaces using the Tailored Lighting Method. The space has a general lighting of 0.75 W/ft<sup>2</sup> and decorative lighting of 0.2 W/ft<sup>2</sup>.
  14. Baseline Tailored Lighting Method/Medium Office-CZ-6, Run14- This test verifies if the applicant software applies the trade-off requirements of the Tailored Lighting Method appropriately. Proposed Model is a medium office building in climate Zone 6 with the following characteristics-
    - Perimeter zones on all floors are modelled as main entry spaces using the Tailored Lighting Method. The space has a general lighting of 0.8 W/ft<sup>2</sup> and task lighting of 0.1 W/ft<sup>2</sup>.
    - Core zones on all floors are modelled as waiting spaces using the Tailored Lighting Method. The space has a general lighting of 0.6 W/ft<sup>2</sup> and decorative lighting of 0.2 W/ft<sup>2</sup>.
  15. Baseline Tailored Lighting Method/Medium Office-CZ-6, Run15- This test verifies if the applicant software applies the trade-off requirements of the Tailored Lighting Method appropriately. Proposed Model is a medium office building in climate Zone 6 with the following characteristics-
    - Perimeter zones on all floors are modelled as main entry spaces using the Tailored Lighting Method. The space has a general lighting of 1.1 W/ft<sup>2</sup> and task lighting of 0.2 W/ft<sup>2</sup>.
    - Core zones on all floors are modelled as waiting spaces using the Tailored Lighting Method. The space has a general lighting of 0.5 W/ft<sup>2</sup>.

16. Baseline Lighting Control Test/Small Office-CZ-6, PAF Run16- This test verifies if the applicant software models lighting power density and schedules for eligible California Power adjustment factors as required by the NACM2013. The proposed model is a small office building (area=5500 sq ft) with demand responsive lighting controls. The model files shall be examined to verify whether adjustment factors are applied as per the requirements in NACM 2013.
17. Baseline Lighting Control Test/Warehouse-CZ-6, Daylightcontrol Run17- This test verifies the ability of the applicant software to model daylighting controls as per the requirements of the 2013 ACM. The proposed model is a warehouse building in CZ-6 with the following characteristics-
  - The building has three spaces – Office, Fine Storage and Bulk Storage. The office space gets daylighting from four windows. Fine Storage gets daylighting from skylights and bulk storage gets both sidelighting from windows and skylighting.
  - Daylighting controls are installed in primary and skylit daylit areas in all spaces and in the secondary daylit area of the Bulk Storage.
  - The installed general lighting power controlled by daylight controls is X Watts.
  - The illuminance setpoint at Reference positions are-

The baseline model inputs shall be verified for-

  - Daylight control type
  - Reference position and illuminance setpoint .
18. Baseline Ext. Light, SHW Test/Large Office-CZ-6, Run18- This test verifies if the NACM rules for exterior lighting is applied accurately for Exterior lighting power, exterior lighting control and schedules. This test also verifies if the Service hot Water systems are modelled correctly. The proposed building is a large office building in climate zone 6, with the following characteristics-
  - a. Hot water load of 106 Btuh/person.
  - b. Thermal efficiency of 0.78
  - c. An exterior hardscape comprising of –
    - i. Driveway of dimensions 20x30 feet with lighting load of 1115 Watts
    - ii. Parking lot of dimensions 180x56 feet with lighting load of 6566 Watts
    - iii. 2 sidewalks of dimensions 6x30 feet with total lighting load of 977 Watts
    - iv. A building entrance door light of 90 Watts.
    - v. 50 square feet of hardscape ornamental light of 2 Watts.
    - vi. Lighting load of 6566 Watts on the building façade.
    - vii. Signage of 40 square feet with lighting load of 80 Watts.
19. Baseline HVAC Test/Small Office-CZ-6, System Type Run19- This test checks if the applicant software models the baseline HVAC system in accordance with the requirements of NACM 2013. The proposed model is a small office building in climate zone 6 with the following characteristics-
  - DX cooling
  - Cooling COP-3.84
  - Gas Furnace Heating
  - Thermal Efficiency – 80%
  - Constant Volume Fan

The following baseline model inputs shall be verified-

  - HVAC System Type
  - Heating and Cooling Type
  - Heating and Cooling Efficiency
  - System Sizing
  - Maximum and minimum supply air temperature
  - Fan Control Method
  - Cooling and heating efficiency curve

- Cooling, Heating and Fan Schedule
20. Baseline HVAC Test/Medium Office-CZ-6, System Type Run20- This test checks if the applicant software models the baseline HVAC system in accordance with the requirements of NACM 2013. The proposed model is a medium office building in climate zone 6 with the following characteristics-
- Core, Mid and Top Bottom Zones (Cooling load= 110,000 Btuh)-Electric Heat pump and constant volume fan.
  - All Perimeter zones- DX Cooling and Hot water Boiler with reheat and variable volume fan.
  - Cooling Efficiency-
  - Heating Efficiency –
- The following baseline model inputs shall be verified-
- HVAC System Type
  - Heating and Cooling Type
  - Heating and Cooling Efficiency
  - System Sizing
  - Maximum and minimum supply air temperature
  - Sat Reset Control
  - Economizer Type and limits
  - Fan Power
  - Fan Control Method
  - Cooling and heating capacity adjustment curve
  - Cooling and heating efficiency curve
  - Cooling, Heating and Fan Schedule
  - Terminal heat type and capacity.
  - Boiler type and Number of boilers
  - Boiler Heat loss, boiler minimum unloading ratio
  - Boiler Performance Curve
  - Hot water supply and return temperature
  - Boiler pump type
  - Pump motor power and efficiency.
  - Pump part load curve.
21. Baseline HVAC Test/Large Office-CZ-6, System Type Run 21- This test checks if the applicant software models the baseline HVAC system in accordance with the requirements of NACM 2013. The proposed model is a Large office building in climate zone 6 with the following characteristics-
- Basement Zone is a computer room with cooling only variable air volume system.
  - All other zones have a Built-up VAV system.
  - Cooling Efficiency-
  - Heating Efficiency –
- The following baseline model inputs shall be verified-
- HVAC System Type
  - Heating and Cooling Type
  - Heating and Cooling Efficiency
  - System Sizing
  - Maximum and minimum supply air temperature
  - Sat Reset Control
  - Economizer Type and limits

- Fan Power
  - Fan Control Method
  - Cooling, Heating and Fan Schedule
  - Terminal heat type and capacity.
  - Boiler type and Number of boilers
  - Boiler Heat loss, boiler minimum unloading ratio
  - Boiler Performance Curve
  - Hot water supply and return temperature
  - Boiler pump type
  - Pump motor power and efficiency.
  - Pump part load curve.
  - Chiller Type and Number of chillers
  - Chiller fuel, capacity and efficiency
  - Chiller Minimum Unloading ratio
  - Chiller cooling capacity and adjustment curves
  - Chilled water supply and return air temperature
  - Condenser Type
  - Cooling Tower Fan control type and horse power
  - Cooling Tower Set Point Control
  - Pump Control Type, Motor Power, Efficiency and design flow rate
22. Baseline HVAC Test/Warehouse-CZ-6, System Type Run22- This test checks if the applicant software models the baseline HVAC system in accordance with the requirements of NACM 2013. The proposed model is a Warehouse building in climate zone 6 with the following characteristics-
- Zones are served by a gas furnace heat only system.
  - Heating Efficiency –
- The following baseline model inputs shall be verified-
- HVAC System Type
  - Heating and Cooling Type
  - Heating and Cooling Efficiency
  - System Sizing
  - Maximum and minimum supply air temperature
  - Sat Reset Control
  - Economizer Type and limits
  - Fan Power
  - Fan Control Method
  - Cooling, Heating and Fan Schedule

#### **3.4.2.4 Results Comparison**

The applicant shall perform all tests specified in Section IV and report the outputs in the forms provided in Appendix B.

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### **3.5 California Calculation Procedures**

California recognizes that there are multiple options for calculating energy impacts of certain building features, including:

- Duct efficiency
- Water heating for multi-family
- Heat transfer from slab-on-grade
- Daylighting

The approach taken for these building features is to specify the required inputs to the compliance software, but allow the software to use its own algorithms or external procedures as appropriate. These building features will be accompanied by a compliance test to verify that the software produces results in reasonable agreement with the Reference Method.

**DETAILS TBD.**

## 4. Content and Format of Standard Reports

**NOTE! THIS CHAPTER WILL NEED REVISION FOR TITLE 24. THE CONTENT OF THE REPORTS MAY CHANGE BASED ON THE NEEDS FOR COMPLIANCE ENFORCEMENT.**

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### 4.1 Overview

THE NUMBER, STRUCTURE AND CONTENT OF THE REPORTS WILL BE DETERMINED.

This chapter provides a summary of the requisite content and format of the Title 24 standard reports. These reports standardize the way energy modeling output data is delivered to the California Energy Commission, either in electronic or printed format. Electronically formatted output reports may be uploaded to the CEC registry according to procedures TBD.

#### 4.1.1 Content

CONTENT TBD.

#### 4.1.2 Format

FORMAT TBD.

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### 4.2 Electronic Format: XML

A POSSIBLE OPTION IS FOR THE COMPLIANCE SOFTWARE TO GENERATE REPORTS IN AN ELECTRONIC FORMAT, SO THAT THEY MAY BE READILY UPLOADED TO THE COMMISSION OR OTHER APPROPRIATE AHJ. THIS FEATURE HAS NOT YET BEEN INCLUDED IN THE SCOPE OF THE COMPLIANCE REPORTS. THE DETAILS OF THE COMPLIANCE FORMS AND REPORTS NEED TO BE SPECIFIED.

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### 4.3 Hard Copy Format: PDF

The compliance software will produce required compliance reports for new construction or alterations projects. The following section provides examples of the automatically generated standard reports. These examples are representative of a typical report output; however, they are not exhaustive.

**CONTENTS TBD**

## 5. Building Descriptors Reference

### 5.1 Overview

This chapter specifies for each building descriptor the rules that apply to the proposed design and to the standard design.

#### 5.1.1 Definition of Building Descriptors

Building descriptors provide information about the proposed design and the standard design. In this chapter, the building descriptors are discussed in the generic terms of engineering drawings and specifications. By using generic building descriptors, this manual avoids bias toward one particular energy simulation engine. The building descriptors in this chapter are compatible with commonly used simulation software.

Each energy simulation program has its own way of accepting building information. EnergyPlus, for instance, uses a comma delimited data file called an IDF file. DOE-2 uses BDL (building design language) to accept information. It is the responsibility of the compliance software to translate the generic terms used in this chapter into the “native language” of the simulation program. Figure 3 illustrates the flow of information.

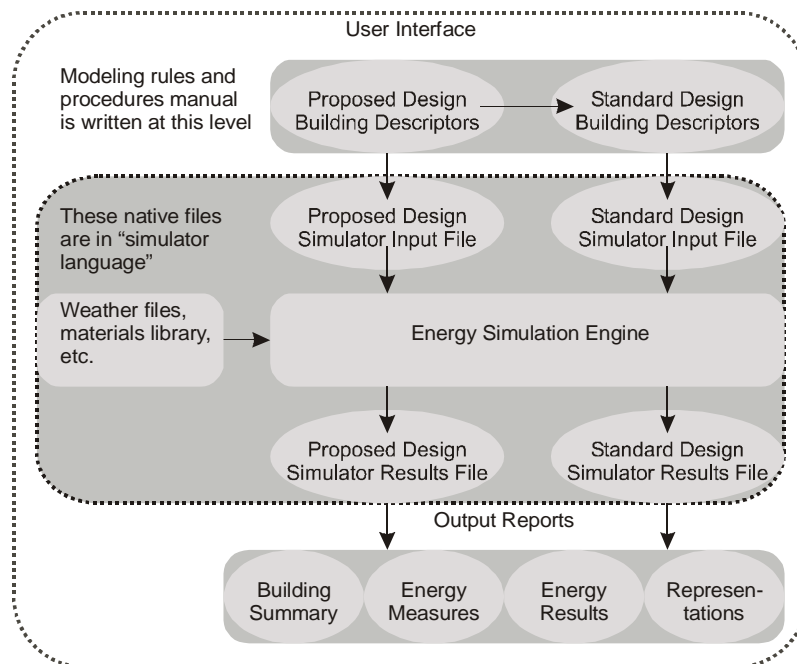


Figure 3 – Information Flow

### 5.1.2 HVAC System Map

The HVAC system in the standard design depends on the primary building activity, the size of the building and the energy source used for heating in the proposed design. Details about these systems are provided in subsequent sections.

Many of the building descriptors have a one-to-one relationship between the proposed design and the standard design, for example, every wall in the proposed design has a corresponding wall in the standard design. However, for HVAC systems, this one-to-one relationship generally does not hold. The HVAC system serving the proposed design and the standard design may be completely different, each with different components, etc.

HVAC system in the *standard design* shall be selected from Table 1 – HVAC System Map, and be based on building type, number of floors, conditioned floor area, and heating source. Additionally, the selected system shall conform to the descriptions in Table 2 – HVAC System Descriptions.

For systems 1, 3, 7, 10 and 11 each thermal zone shall be modeled with its own HVAC system. For systems 5, 6, and 9, each floor shall be modeled with a separate HVAC system. Floors with identical thermal zones can be grouped for modeling purposes. The standard design heating source is natural gas where gas is available at the site. Where gas is not available the heating source is propane.

Table 5 – HVAC System Map

Building Type	Standard Design System
Residential	System 1 – PTAC
High-rise Residential and Hotel Guestrooms	System 2 – Four-pipe fan coil (FPFC)
Nonresidential and 3 Floors or Less than <25,000 ft <sup>2</sup>	System 3 – PSZ AC
Nonresidential and 4 or 5 Floors and <25,000 ft <sup>2</sup> or 5 Floors or Less and 25,000 ft <sup>2</sup> to 150,000 ft <sup>2</sup>	System 5 – PVAV with Reheat**
Nonresidential and More than 5 Floors or >150,000 ft <sup>2</sup>	System 6 – VAV with reheat**
Nonresidential and 3 Floors or Less and less than 25,000 ft <sup>2</sup> and zone cooling load $\geq$ 110,000 Btu/h*	System 7 – Single Zone VAV
Heated Only Storage	System 9 – Heating and Ventilation
Total computer room design cooling load is over 3,000,000 Btu/h or the non-computer loads are served by System Types 5 or 6 (Packaged VAV or Built-up VAV)	System 10 – CRAH Units
Computer rooms that do not meet the conditions for System 10, CRAH	System 11 – CRAC Units

\* The single zone VAV system 7 applies to thermal zones with design cooling loads greater than 110,000 Btu/h (and in 1/1/2014, 75,000 Btu/h, and 1/1/2016, 65,000 Btu/h). Thermal zones with smaller design cooling loads shall use the package single zone system 3.

\*\* For laboratory spaces in a building having a total laboratory exhaust rate greater than 5000 cfm, use a single system of type 5 or 6 with a design supply air to room air temperature difference of 17F.

Note: A “Floor” is considered a “Habitable Story”, defined in the Standards as a story that is at least 50 percent above grade.

Table 6 – HVAC System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
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1 – PTAC	Package terminal air conditioner	Constant volume	DX	Hot water fossil fuel boiler
2 – FPFC	Four-pipe fan coil	Constant volume	Chilled Water	Hot water fossil fuel boiler
3 – PSZ AC	Package single zone	Constant volume	DX	Fossil fuel furnace
5 – PVAV reheat	Package VAV reheat	Variable volume	DX	Hot water fossil fuel boiler
6 – VAV reheat	VAV reheat	Variable volume	Chilled water	Hot water fossil fuel boiler
7 – SZVAV	Single Zone VAV	Two-Speed*	DX	Fossil fuel furnace
9 – Heating ventilation	Heating only	Constant volume	None	Gas furnace
10 – CRAH Units	CR Air Handler	Variable volume	Chilled water	N/A
11 – CRAC Units	CR Air Conditioner	Variable volume	DX	N/A

\* The supply fan controls shall modulate down to a minimum of 2/3 of the full fan speed or lower at low cooling demand, with a maximum part-load fan power of 40% at 2/3 fan speed.

There are several important exceptions to the HVAC mapping rules that apply to spaces with unusual internal heat gains, different schedules, special pressurization requirements, or unique outside air needs. These exceptions will typically apply to laboratories, data centers, and many spaces in healthcare facilities. See Chapter 5 for the special requirements for these building types. The exceptions are described below:

- Separate occupancies in mixed use buildings are served by separate standard design systems. Examples include residential spaces located over retail and other similar conditions. See Chapter 2, Space Use Classification Considerations, for a detailed description of when spaces with different occupancies may be served by a single system. However, when the equivalent weekly full-load hours between occupancies in mixed use buildings varies by more than 40 hours; occupancies shall be served by separate HVAC systems.
- A separate standard design system shall serve laboratories or a group of laboratories with an exhaust system designed for 5,000 cfm or more of air movement. The standard design system serving the laboratory spaces shall be system 5 (PVAV with hot water reheat) or 6 (VAV with hot water reheat). The PVAV or VAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system.
- Spaces that do not trigger the laboratory exception above may still have a separate standard design system. System 3 (PSZ-AC) shall serve spaces in the standard design (depending on the heating source for the building) when one of the following conditions apply:
  - Spaces on a floor have significantly different schedules or internal heat loads. Heat gain differences of more than 10 Btu/h-ft<sup>2</sup> or operation schedule differences of more than 40 hours/week trigger this exception.
  - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates". Many laboratory spaces with fume hoods would likely trigger this exception.

These special systems serve just the spaces that trigger the exceptions. The rest of the building/floor is served by the standard design HVAC system as indicated in Table 1.

### 5.1.3 Organization of Information

Building descriptors are grouped under objects or building components. A wall or exterior surface (an object) would have multiple building descriptors dealing with its geometry, thermal performance, etc. Each building descriptor contains the following pieces of information.

#### **Building Descriptor Title**

<i>Applicability</i>	Information on when the building descriptor applies to the proposed design
<i>Definition</i>	A definition for the building descriptor
<i>Units</i>	The units that are used to prescribe the building descriptor. A "List" indicates that a fixed set of choices applies and the user shall only be allowed to enter one of the values in the list.
<i>Input Restrictions</i>	Any restrictions on information that may be entered for the proposed design
<i>Standard Design</i>	This defines the value for the "Standard Design" or baseline building is applied for this building descriptor. A value of "Same as proposed" indicates that the building descriptor is neutral; that is, the value is set to match the proposed design value. In many cases, the value may be fixed, or may be determined from a table lookup. In some cases the input may not be applicable: for example, heat recovery effectiveness is not applicable because the standard design (baseline building) does not have heat recovery.

## 5.2 Project Data

### 5.2.1 General Information

#### **Project Name**

<i>Applicability</i>	All projects
<i>Definition</i>	Name used for the project, if one is applicable
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is optional for the proposed design.
<i>Standard Design</i>	Not applicable

#### **Project Address**

<i>Applicability</i>	All projects
<i>Definition</i>	Street address, city, state, and zip code
<i>Units</i>	Up to 50 alphanumeric characters on each of two lines
<i>Input Restrictions</i>	Input is mandatory for the proposed design.
<i>Standard Design</i>	Not applicable

**Project Owner**

<i>Applicability</i>	All projects
<i>Definition</i>	Owner(s) of the project or individual or organization for whom the building permit is sought. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is optional for the proposed design.
<i>Standard Design</i>	Not applicable

**Architect**

<i>Applicability</i>	All projects
<i>Definition</i>	Architect responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design.
<i>Standard Design</i>	Not applicable

**HVAC Engineer**

<i>Applicability</i>	All projects
<i>Definition</i>	HVAC Engineer responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design. Information should include name, title, organization, email, and phone number.
<i>Standard Design</i>	Not applicable

**Lighting Engineer/Designer**

<i>Applicability</i>	All projects
<i>Definition</i>	Lighting Engineer/Designer responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design.
<i>Standard Design</i>	Not applicable

**Energy Modeler**

<i>Applicability</i>	All projects
<i>Definition</i>	Individual responsible for performing the compliance analysis. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design.
<i>Standard Design</i>	Not applicable

**Date**

<i>Applicability</i>	All projects
<i>Definition</i>	Date of completion of the compliance analysis or the date of its most-recent revision
<i>Units</i>	Date format
<i>Input Restrictions</i>	Input is mandatory for the proposed design.
<i>Standard Design</i>	Not applicable

**5.2.2 Building Model Classification**

The structure of this manual supports multiple purposes and multiple baselines. For example, a baseline used for Title 24 compliance might be separate from a baseline used for green building ratings or ASHRAE 90.1 energy cost budget method. A building descriptor “Purpose” could be used to identify different baselines, but is not within the current scope of this manual.

**Space Classification Type**

<i>Applicability</i>	All projects
<i>Definition</i>	<p>One of two available classification methods for identifying the function of the building or the functions of spaces within the building, which in turn determine energy-related requirements for the standard design. Appendix 5.4A lists the building classifications that are available under the complete building method and area category method.</p> <p>The Complete Building method uses the same space definitions for all spaces within a building, and the building type must match one of the types in the list in the Appendix.</p> <p>The Area Category method uses a separate space classification for each space in the building according to its function.</p>
<i>Units</i>	List: Complete Building, Area Category
<i>Input Restrictions</i>	For multi-use buildings, the building may be divided and a different building classification may be assigned to each part. Either the complete building method or the area category method must be used, but the two classification methods may not be mixed within a single compliance run.
<i>Standard Design</i>	Same as proposed

**Building Classification**

<i>Applicability</i>	When the complete building method is used instead of the area category method of classifying activity in the building
<i>Definition</i>	<p>The building type or principal activity. One of two available classification methods for identifying the function of the building or the functions of spaces within the building, which in turn determine energy-related requirements for the standard design. Appendix 5.4A lists the building classifications that are available under the complete building method.</p>
<i>Units</i>	List: Choose a building activity from Appendix 5.4A
<i>Input Restrictions</i>	For multi-use buildings, the building may be divided and a different building classification may be assigned to each part. Either the complete building method or the area category method must be used, but the two classification methods may not be mixed within a single compliance run.

*Standard Design*    Same as proposed

### 5.2.3 Geographic and Climate Data

The following data needs to be specified or derived in some manner. Software developers may use any acceptable method to determine the data. For California, city, state and county are required to determine climate data from the available data in Reference Appendix JA2

#### Zip Code

<i>Applicability</i>	All projects
<i>Definition</i>	California postal designation
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Not applicable

#### Latitude

<i>Applicability</i>	All projects
<i>Definition</i>	The latitude of the project site
<i>Units</i>	Degrees (°)
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Latitude of representative city from Reference Appendix JA2

#### Longitude

<i>Applicability</i>	All projects
<i>Definition</i>	The longitude of the project site
<i>Units</i>	Degrees (°)
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Longitude of representative city from Reference Appendix JA2

#### Elevation

<i>Applicability</i>	All projects
<i>Definition</i>	The height of the building site above sea level
<i>Units</i>	Feet (ft)
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Elevation of representative city from Reference Appendix JA2

#### California Climate Zone

<i>Applicability</i>	All projects
<i>Definition</i>	One of the 16 California climate zones
<i>Units</i>	

	List
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Same as proposed

**Daylight Savings Time Observed**

<i>Applicability</i>	All projects
<i>Definition</i>	An indication that daylight savings time is observed. The schedules of operation are shifted by an hour twice a year and this affects solar gains, temperature and other factors.
<i>Units</i>	Boolean (True/False)
<i>Input Restrictions</i>	True
<i>Standard Design</i>	True

**County**

<i>Applicability</i>	All projects
<i>Definition</i>	The county where the project is located
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Standard Design</i>	County of representative city from Reference Appendix JA2

**City**

<i>Applicability</i>	All projects
<i>Definition</i>	The city where the project is located
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Representative city from Reference Appendix JA2

**Design Day Data**

<i>Applicability</i>	All projects
<i>Definition</i>	A data structure indicating design day information used for the sizing of the proposed system. Note that this information may not necessarily match the information used in the annual compliance simulation.
<i>Units</i>	Data Structure: contains the following: Design DB (0.5%), Mean Coincident Wet-Bulb, Daily Range, Day of Year
<i>Input Restrictions</i>	Must match climate data in Reference Appendix JA2
<i>Standard Design</i>	Not applicable

**Weather File**

<i>Applicability</i>	All projects
<i>Definition</i>	The hourly (i.e., 8,760 hour per year) weather data to be used in performing the

building energy simulations. Weather data must include outside dry-bulb temperature, outside wet-bulb temperature, atmospheric pressure, wind speed, wind direction, cloud amount, cloud type (or total horizontal solar and total direct normal solar), clearness number, ground temperature, humidity ratio, density of air, and specific enthalpy.

*Units* Data file

*Input Restrictions* The weather file selected shall be in the same climate zone as the proposed design. If multiple weather files exist for one climate zone then the weather file closest in distance to the proposed design and in the same climate zone shall be used.

*Standard Design* Weather data shall be the same for both the proposed design and standard design.

### Ground Reflectance

*Applicability* All projects

*Definition* Ground reflectance affects daylighting calculations and solar gain. The reflectance can be specified as a constant for the entire period of the energy simulation or it may be scheduled, which might be appropriate to account for snow cover in the winter.

*Units* Data structure: schedule, fraction

*Input Restrictions* None

*Standard Design* Ground reflectance shall be the same for both the proposed design and the standard design when it is specified to capture snow cover.

### Local Terrain

*Applicability* All projects

*Definition* An indication of how the local terrain shields the building from the prevailing wind. Estimates of this effect are provided in the ASHRAE Handbook of Fundamentals.

*Units* List: the list shall contain only the following choices:

Description	Exponent ( $\alpha$ )	Boundary layer thickness, $\delta$ (m)
Flat, open country	0.14	270
Rough, wooded country, Suburbs	0.22	370
Towns and cities	0.33	460
Ocean	0.10	210
Urban, industrial, forest	0.22	370

The exponent and boundary layer are used in the following equation to adjust the local wind speed:

$$V_z = V_{ref} \left( \frac{\delta_{ref}}{z_{ref}} \right)^{\alpha_{ref}} \left( \frac{z}{\delta} \right)^{\alpha}$$

where

$z$  = altitude, height above ground (m)

$V_z$  = wind speed at altitude  $z$  (m/s)

$\alpha$  = wind speed profile exponent at the site

$\delta$  = wind speed profile boundary layer thickness at the site (m)

$z_{met}$  = height above ground of the wind speed sensor at the meteorological station (m)

$V_{met}$  = wind speed measured at the meteorological station (m/s)

$\alpha_{met}$  = wind speed profile exponent at the meteorological station

$\delta_{met}$  = wind speed profile boundary layer thickness at the meteorological station. (m)

The wind speed profile coefficients  $\alpha$ ,  $\delta$ ,  $\alpha_{met}$ , and  $\delta_{met}$ , are variables that depend on the roughness characteristics of the surrounding terrain. Typical values for  $\alpha$  and  $\delta$  are shown in the table above:

*Input Restrictions* Weather data should be representative of the long term conditions at the site

*Standard Design* The standard design terrain should be equal to the proposed design

## 5.2.4 Site Characteristics

### Shading of Building Site

<i>Applicability</i>	All projects
<i>Definition</i>	Shading of building fenestration, roofs, or walls by other structures, surrounding terrain, vegetation, and the building itself
<i>Units</i>	Data structure
<i>Input Restrictions</i>	The default and fixed value is for the site to be unshaded. External shading from other buildings or other objects is not modeled for Title 24 compliance in the ACM.
<i>Standard Design</i>	The proposed design and standard design are modeled with identical assumptions regarding shading of the building site.

## 5.2.5 Calendar

### Year for Analysis

<i>Applicability</i>	All projects
<i>Definition</i>	The calendar year to be used for the annual energy simulations. This input determines the correspondence between days of the week and the days on which weather events on the weather tape occur and has no other impact.
<i>Units</i>	List: choose a year (other than a leap year).
<i>Input Restrictions</i>	Use year 1991.
<i>Standard Design</i>	Same calendar year as the proposed design

### Schedule of Holidays

<i>Applicability</i>	All projects
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<i>Definition</i>	A list of dates on which holidays are observed and on which holiday schedules are used in the simulations	
<i>Units</i>	Data structure	
<i>Input Restrictions</i>	The following ten holidays represent the prescribed set. When a holiday falls on a Saturday, the holiday is observed on the Friday proceeding the Saturday. If the holiday falls on a Sunday, the holiday is observed on the following Monday.	
	New Year's Day	January 1
	Martin Luther King Day	Third Monday in January
	Presidents Day	Third Monday in February
	Memorial Day	Last Monday in May
	Independence Day	July 4
	Labor Day	First Monday in September
	Columbus Day	Second Monday in October
	Veterans Day	November 11
	Thanksgiving Day	Fourth Thursday in November
	Christmas Day	December 25
<i>Standard Design</i>	The standard design shall observe the same holidays specified for the proposed design.	

## 5.3 Thermal Zones

A thermal zone is a space or collection of spaces having similar space-conditioning requirements, the same heating and cooling setpoint, and is the basic thermal unit (or zone) used in modeling the building. A thermal zone will include one or more spaces. A thermal zone can include more than one HVAC zone, but HVAC zones may not split between thermal zones.

### 5.3.1 General Information

#### Thermal Zone Name

<i>Applicability</i>	All projects
<i>Definition</i>	A unique identifier for the thermal zone made up of 50 or fewer alphanumeric characters.
<i>Units</i>	Text
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Not applicable

#### Thermal Zone Description

<i>Applicability</i>	All projects
<i>Definition</i>	A brief description of the thermal zone that identifies the spaces that make up the thermal zone or other descriptive information. The description should tie the thermal zone to the building plans.
<i>Units</i>	Text
<i>Input Restrictions</i>	

	None
<i>Standard Design</i>	Not applicable

**Thermal Zone Type**

<i>Applicability</i>	All projects
<i>Definition</i>	Designation of the thermal zone as directly conditioned space, indirectly conditioned space (i.e., conditioned only by passive heating or cooling from an adjacent thermal zone), or plenum (i.e., unoccupied but partially conditioned as a consequence of its role as a path for returning air).
<i>Units</i>	List: directly conditioned, indirectly conditioned, unconditioned or plenum
<i>Input Restrictions</i>	The default thermal zone type is “directly conditioned.”
<i>Standard Design</i>	The descriptor is identical for the proposed design and standard design.

**System Name**

<i>Applicability</i>	All projects
<i>Definition</i>	The name of the HVAC system that serves this thermal zone. The purpose of this building descriptor is to link the thermal zone to a system (child points to parent). Software can make this link in other ways.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	The standard design may have a different system mapping if the standard design has a different HVAC type than the proposed design.

**Floor Area**

<i>Applicability</i>	All projects
<i>Definition</i>	The gross floor area of a thermal zone; including walls and minor spaces for mechanical or electrical services such as chases that are not assigned to other thermal zones. Larger mechanical spaces and electrical rooms should not be combined.
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions</i>	The floor area of the thermal zone is derived from the floor area of the individual spaces that make up the thermal zone.
<i>Standard Design</i>	Same as proposed design

**5.3.2 Interior Lighting**

Inputs for interior lighting are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either model the lighting separate for each space and sum energy consumption and heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that

the lighting power used at the thermal zone level is equal to the combination of lighting power for each of the spaces contained in the thermal zone.

In some cases, combining lighting power at the space level into lighting power for the thermal zone may be challenging and would have to be done at the level of each time step in the simulation. These cases include:

- A thermal zone that contains some spaces that have daylighting and others that do not.
- A thermal zone that contains spaces with different schedules of operation.
- A thermal zone that contains some spaces that have a schedule adjusted in some way for lighting controls and other spaces that do not.
- Combinations of the above.

### 5.3.3 Receptacle Loads

Inputs for receptacle and process loads are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either model the receptacle and process loads separate for each space and sum energy consumption and heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that the receptacle and process loads used at the thermal zone level are equal to the combination of receptacle and process loads for each of the spaces contained in the thermal zone.

When the spaces contained in a thermal zone have different schedules, combining receptacle and process loads from the space level may be challenging and would have to be done at the level of each time step in the simulation. See discussion above on lighting.

### 5.3.4 Occupants

Inputs for occupant loads are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either model the occupant loads separate for each space and the heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that the occupant loads used at the thermal zone level are equal to the combination of occupant loads for each of the spaces contained in the thermal zone.

When the spaces contained in a thermal zone have different occupant schedules, rolling up occupant loads from the space level may be challenging and would have to be done at the level of each time step in the simulation. Spaces with differences in full-load equivalent operating hours of more than 40 hours per week shall not be combined in a single zone. See discussion above on lighting.

### 5.3.5 Infiltration

#### ***Infiltration Method***

<i>Applicability</i>	All projects
<i>Definition</i>	Energy simulation programs have a variety of methods for modeling uncontrolled air leakage or infiltration. Some procedures use the effective leakage area which is

	generally applicable for small residential scale buildings. The component leakage method requires the user to specify the average leakage through the building envelope per unit area (ft <sup>2</sup> ). Other methods require the specification of a maximum rate, which is modified by a schedule.
<i>Units</i>	List: effective leakage area, component leakage, air changes per hour, or other method supported by the energy analysis software.
<i>Input Restrictions</i>	For California Compliance and Reach, the component leakage area is prescribed; a fixed infiltration rate shall be specified and calculated as a leakage per area of exterior envelope, including the <i>gross area</i> of exterior walls, roofs, and exposed floors, but excluding slabs on grade and interior partitions.
<i>Standard Design</i>	The infiltration method used for the standard design shall be the same as the proposed design.

### Infiltration Data

<i>Applicability</i>	All projects
<i>Definition</i>	Information needed to characterize the infiltration rate in buildings. The required information will depend on the infiltration method selected above. For the effective leakage area method, typical inputs are leakage per exterior wall area in ft <sup>2</sup> or other suitable units and information to indicate the height of the building and how shielded the site is from wind pressures. Only zones with exterior wall area are assumed to be subject to infiltration.
<i>Units</i>	A <i>data structure</i> is required to define the effective leakage area model,
<i>Input Restrictions</i>	For the California Compliance and Reach, infiltration shall be calculated each hour using Equation 1:

$$Infiltration = I_{design} \cdot F_{schedule} \cdot (A + B \cdot |t_{zone} - t_{odb}| + C \cdot ws + D \cdot ws^2) \quad (1)$$

where:

<i>Infiltration</i>	= zone infiltration airflow (m <sup>3</sup> /s-m <sup>2</sup> )
<i>I<sub>design</sub></i>	= design zone infiltration airflow (m <sup>3</sup> /s-m <sup>2</sup> )
<i>F<sub>schedule</sub></i>	= fractional adjustment from a user input schedule (unitless)
<i>t<sub>zone</sub></i>	= zone air temperature (°C)
<i>t<sub>odb</sub></i>	= outdoor dry bulb temperature (°C)
<i>ws</i>	= the windspeed (m/s)
<i>A</i>	= overall coefficient (unitless)
<i>B</i>	= temperature coefficient (1/°C)
<i>C</i>	= windspeed coefficient (s/m)
<i>D</i>	= windspeed squared coefficient (s <sup>2</sup> /m <sup>2</sup> )

For the proposed design, *I<sub>design</sub>* shall have a default of 0.0448 cfm/ft<sup>2</sup> (0.000228 m<sup>3</sup>/s-m<sup>2</sup>) times the gross wall area exposed to ambient outdoor air. A, B and D shall be zero. C shall be 0.10016 hr/mile (0.224 s/m).

<i>Standard Design</i>	The infiltration data for the standard design shall be the same as the proposed design unless the proposed design employs specific measures that go beyond the mandatory measures..
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### Infiltration Schedule

*Applicability*

	When an infiltration method is used that requires the specification of a schedule
<i>Definition</i>	With the ACH method and other methods (see above), it may be necessary to specify a schedule that modifies the infiltration rate for each hour or time step of the simulation. Typically the schedule is either on or off, but can also be fractional.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	For the purpose of California Compliance and Reach, the infiltration schedule shall be prescribed based on the HVAC System operating schedules from Appendix 5.4B. The infiltration schedule shall be set equal to 1 when the HVAC system is off, and 0.25 when the HVAC system is on. This is based on the assumption that when the HVAC system is on it brings the pressure of the interior space above the pressure of the exterior, and decreasing the infiltration of outside air. When the HVAC system is off, interior pressure drops below exterior pressure and infiltration increases.
<i>Standard Design</i>	The infiltration schedule for the standard design shall be the same as the proposed design.

### 5.3.6 Natural Ventilation

Natural ventilation may be modeled for a thermal zone in the proposed design when the following conditions are met:

- The thermal zone does not have an air conditioning system.
- The temperature of the thermal zone does not exceed the cooling setpoint temperature for more than 300 hours for the year of the simulation with just the natural ventilation system operating.

Under these circumstances, the thermal zone in the proposed design is modeled with no air conditioning when the natural ventilation system maintains temperature. For periods when the space temperature is greater than the cooling setpoint, an air conditioner like the one for the standard design is assumed to operate to maintain temperature. The fans in this simulated system cycle with loads. The corresponding thermal zone in the standard design is modeled with air conditioning and the fans operate continuously.

For California Compliance, natural ventilation shall not be modeled. Thermal zones in the proposed design that have no cooling system are modeled with the same standard design cooling system.

#### Natural Ventilation Method

<i>Applicability</i>	All thermal zones with natural ventilation
<i>Definition</i>	The method used to model natural ventilation. The choices will depend to some extent on the capabilities of the energy simulation program. One procedure that could be used with most energy simulation programs would be to approximate the effect of natural ventilation by scheduling a high rate of infiltration when conditions are right. The schedule would typically be developed through computational fluid dynamic software or with other software that is capable of estimating the cooling benefit of natural ventilation and relating it to climate so that the schedule can be developed.
<i>Units</i>	List: choices depend on the capabilities of the energy simulation program.
<i>Input Restrictions</i>	None
<i>Standard Design</i>	The standard design is not modeled with natural ventilation.

#### Air Flow Rate

<i>Applicability</i>	All projects with natural ventilation that use a method that require the specification of an air flow rate
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<i>Definition</i>	The rate of air flow through the thermal zone when the natural ventilation system is operating
<i>Units</i>	Air changes per hour or cfm
<i>Input Restrictions</i>	The air flow rate for the proposed design shall be determined using sound engineering methods and supporting documentation shall be provided.
<i>Standard Design</i>	The standard design is not modeled with natural ventilation.

#### **Natural Ventilation Schedule**

<i>Applicability</i>	All projects with natural ventilation that use a method that requires a schedule
<i>Definition</i>	A schedule that modifies the airflow rate through the thermal zone dictates when windows can be opened to provide natural ventilation.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The schedule for the proposed design shall be determined using sound engineering methods and keyed to outdoor temperature and perhaps other conditions on the weather file used for the simulation.
<i>Standard Design</i>	The standard design is not modeled with natural ventilation.

### **5.3.7 Thermal Mass**

This set of building descriptors characterize the thermal mass that is not explicitly captured by the definition of exterior surfaces and interior partitions.

#### **Thermal Response Characteristics**

<i>Applicability</i>	All projects
<i>Definition</i>	<p>This building descriptor only addresses the building contents. The thermal mass associated with floors, interior walls, and other building envelope components is derived from the thermal properties and materials that make up these components. However, if interior partitions are not explicitly entered (see below) their effect may be captured with this input.</p> <p>The thermal capacitance of the building contents are typically specified in terms of the composite weight of the building contents in lb/ft<sup>2</sup> or absolute lb. In this instance, the software assumes an average specific heat for the contents. This input can also be specified as the mass of the contents multiplied times the specific heat of the contents. The latter method would be a summation, since each item may have a different specific heat.</p>
<i>Units</i>	lb/ft <sup>2</sup> or lb
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The interior thermal mass in the standard design shall be the same as the proposed design.

#### **Furniture and Contents**

<i>Applicability</i>	All projects
<i>Definition</i>	A specification of the mass and heat capacity of furniture and other elements in the interior of the building. This includes information about the coverage and weight of furniture in the space as well as how much of the floor is covered by furniture. The

	latter affects how much of the solar gains that enters the space is directed to the floor with delayed heat gain and how much becomes a more instantaneous load.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The interior thermal mass and modeling assumptions in the standard design shall be the same as the proposed design.

## 5.4 Space Uses

Each thermal zone discussed above may be subdivided into HVAC zones and the HVAC zones may be further subdivided into space uses. This section presents the building descriptors that relate to the space uses. Space uses and the defaults associated with them are listed in Appendix 5.4A. Every thermal zone shall have at least one space, as defined in this section. Daylit spaces should generally be separately defined.

### 5.4.1 General Information

#### Space Type

<i>Applicability</i>	All projects
<i>Definition</i>	<p>For identifying space type, either the complete building method or area category method may be used.</p> <p>If lighting compliance is not performed, use either approach, but actual LPDs cannot be entered for the spaces – the LPDs of the building match the standard design.</p> <p>The allowed building types in complete building category or space types in area category is available from Nonresidential Appendix 5.4A. The building or space type determines the following baseline inputs:</p> <ul style="list-style-type: none"> <li>Number of occupants (occupant density)</li> <li>Equipment Power Density</li> <li>Lighting Power Density</li> <li>Hot Water Load</li> <li>Ventilation Rate</li> <li>Schedules (from Appendix 5.4B)</li> </ul>
<i>Units</i>	List
<i>Input Restrictions</i>	<p>Only selections shown in the Appendix 5.4A may be used.</p> <p>For unconditioned spaces, the user must enter “Unconditioned” as the occupancy and ventilation, internal loads and uses are set to zero. Compliance software shall require the user to identify if lighting compliance is performed (lighting plans are included or have already been submitted).</p>
<i>Standard Design</i>	Same as proposed.
<i>Standard Design, Existing Buildings</i>	Same as proposed

**Floor Area**

<i>Applicability:</i>	All projects that use the area category classification method (see above)
<i>Definition:</i>	The floor area of the space. The area of the spaces that make up a thermal zone shall sum to the floor area of the thermal zone.
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions:</i>	Area shall be measured to the outside of exterior walls and to the center line of partitions.
<i>Standard Design</i>	Area shall be identical to the proposed design.
<i>Standard Design, Existing Buildings</i>	Same as proposed

**5.4.2 Occupants**

For space level information on occupancy, lighting and plug load schedules, as well as occupant density, allowed lighting power density, Appendix 5.4A provides a table of allowed space types.

**Number of Occupants**

<i>Applicability</i>	All projects
<i>Definition</i>	The number of persons in a space. The number of persons is modified by an hourly schedule (see below), which approaches but does not exceed 1.0. Therefore, the number of persons specified by the building descriptor is similar to design conditions as opposed to average occupancy.
<i>Units</i>	The number of persons may be specified in an absolute number, ft <sup>2</sup> /person, or persons/1000 ft <sup>2</sup> .
<i>Input Restrictions</i>	The number of occupants is prescribed for Compliance and Reach, and the values are given by Space Type in Appendix 5.4A,.
<i>Standard Design</i>	The number of occupants must be identical for both the proposed and baseline design cases.
<i>Standard Design, Existing Buildings</i>	The number of occupants must be identical for both the proposed and baseline design cases.

**Occupant Heat Rate**

<i>Applicability</i>	All projects
<i>Definition</i>	The sensible and latent heat produced by each occupant in an hour. This depends on the activity level of the occupants and other factors. Heat produced by occupants must be removed by the air conditioning system as well as the outside air ventilation rate and can have a significant impact on energy consumption.
<i>Units</i>	Btu/h specified separately for sensible and latent gains
<i>Input Restrictions</i>	The occupant heat rate is prescribed for California Compliance and Reach.
<i>Standard Design</i>	The occupant heat rate for the baseline building shall be the same as the proposed design.

Standard Design,  
Existing Buildings

Same as proposed

### Occupancy Schedule

<i>Applicability</i>	All projects
<i>Definition</i>	The occupancy schedule modifies the number of occupants to account for expected operational patterns in the building. The schedule adjusts the heat contribution from occupants to the space on an hourly basis to reflect time-dependent usage patterns. The occupancy schedule can also affect other factors such as outside air ventilation, depending on the control mechanisms specified.
<i>Units</i>	Data structure: schedule, fractional.
<i>Input Restrictions</i>	The occupant schedule is a default for California Compliance and Reach. For California Compliance and Reach, an appropriate schedule from Appendix 5.4B shall be used as a default. If values other than those shown in Appendix 5.4A are used, this will be reported as a condition requiring an Exceptional Condition Review by a third party reviewer.
<i>Standard Design</i>	Occupancy schedules are identical for proposed and baseline building designs.
<i>Standard Design, Existing Buildings</i>	Same as proposed

## 5.4.3 Interior Lighting

The building descriptors in this section are provided for each lighting system. Typically a space will have only one lighting system, but in some cases, it could have two or more. Examples include a general and task lighting system in offices or hotel multi-purpose rooms that have lighting systems for different functions. It may also be desirable to define different lighting systems for spaces that are daylit and those that are not.

### Lighting Classification Method

<i>Applicability</i>	Each space in the building
<i>Definition</i>	<p>Indoor lighting power can be specified using the complete building method, area category method or the tailored method.</p> <p>Complete building method can be used for building types listed in Appendix 5.4A. Parking garage portion of the building shall be considered as a separate space. This method cannot be combined with other lighting classification methods described in this section.</p> <p>Area category method can be used for all areas of the building with space types listed in Appendix 5.4A. This method can be used by itself or with the tailored lighting method.</p> <p>Tailored lighting method can be used for spaces with primary function listed in Table 140.6D of the Standards and §140.6(c)3H. The tailored lighting method is intended to accommodate special lighting applications. The tailored lighting method can be used by itself for all areas of the building or with the area category method. For a given area only one classification type can be used.</p>
<i>Units</i>	List
<i>Input Restrictions</i>	Only Complete Building, Area Category or Tailored Lighting are allowed.

*Standard Design* Same as proposed.

*Standard Design,  
Existing Buildings* Same as proposed.

*Table 7- Lighting Specification*

Options:Lighting Classification Method	Complete Building Method	Area Category Method	Tailored Lighting Method
Allowed combinations with other lighting classification methods	None	May be combined with Tailored method	May be combined with Area Category Method
Allowed Regulated lighting power types	General Lighting Power	General Lighting Power Custom Lighting Power	General Lighting Power Custom Lighting Power
Allowed Trade-offs	None	General lighting between spaces using area category method  General lighting between spaces using area category and tailored method.	General lighting between spaces using tailored method  General lighting between spaces using tailored and area category method
Exception: With the Area Category method, custom lighting power can be used only if the tailored lighting method is not used in any area of the building.			

#### **Regulated Interior Lighting Power**

*Applicability* All projects when lighting compliance is performed

*Definition* Total connected lighting power for all regulated interior lighting power. This includes the loads for lamps and ballasts. The total regulated interior lighting power is the sum of general lighting power and applicable custom lighting power. Calculation of lighting power for conditioned spaces is done separately from unconditioned spaces.

*Units* Watts

*Input Restrictions* Derived – not a user input. The proposed value is the sum of the proposed *General Lighting Power* and the proposed *Custom Lighting Power*.

When lighting compliance is not performed, the lighting power may not be entered and is set equal to the lighting level of the baseline building, which is set to the levels for the selected occupancy from Appendix 5.4A.

*Standard Design* For spaces without special task lighting, wall display lighting or similar requirements, this input will be the same as the general lighting power. See the general lighting power building descriptor for details.

With the area category and tailored method regulated interior lighting power for each space will be the sum of general lighting power and allowed custom lighting power.

For alterations where less than 40 luminaires have been modified the standard design is the existing lighting condition before the alteration. If 40 or more luminaires have been modified, the prescriptive requirements for new construction apply.

#### **General Lighting Power**

*Applicability* All spaces or projects

*Definition*

	General lighting power is the power used by installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting, and also known as ambient lighting.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed. For spaces without special task lighting, wall display lighting or similar requirements, this input will be the same as the regulated lighting power.  Trade-offs in general lighting power is allowed between spaces all using the area category method, between spaces all using the tailored lighting method and between spaces that use area category and tailored methods. See Table Lighting Specification Options.
<i>Standard Design</i>	With the complete building classification method, general lighting power is the product of the lighting power density for the building classification from Appendix 5.4A and the conditioned floor area of the space.  With the area category method, general lighting power is the product of the lighting power densities for the space type from Appendix 5.4A and the floor areas for the corresponding spaces.  With the tailored lighting method, general lighting power is the product of the lighting power density for the primary function type in Table 140.6-D of the Standards and floor area of the space. The lighting power density is given as a function of room cavity ratio (RCR) and interior illumination level in Table 140.6-G. <i>No interpolation is allowed for this table.</i>  The general lighting power in the tailored method is calculated by the following steps:  Step 1. Determine illumination level from Table 140.6-D by matching the Primary Function Area in Table 140.6-D with the space type in Appendix 5.4A.  Step 2. Calculate the room cavity ratio (RCR) by using the applicable equation in Table 140.6-F.  Rectangular Rooms: $RCR = 5 \times H \times (L+W) / (L \times W)$  Irregular Rooms: $RCR = 2.5 \times H \times P / A$  <b>Where: L =Length of room; W = Width of room; H =Vertical distance from the work plane to the centerline of the lighting fixture; P = Perimeter of room, and A = Area of room</b>  Step 3. Determine the general lighting in the space(s) using the tailored method by a look-up in Table 140.6-G, where the general lighting LPD is a function of illuminance level and RCR. No interpolation is allowed for this table. A space between two illuminance levels (for example, 150 lux) uses the applicable LPD from the next lower illuminance level (100 lux).
<i>Standard Design, Existing Buildings</i>	For alterations where less than 40 luminaires have been modified, the baseline is the existing lighting condition before the alteration. If 40 or more luminaires have been modified, the general lighting power for the baseline is defined for each space type in Appendix 5.4B.

### Custom Lighting Power

<i>Applicability</i>	All spaces or projects that use the area category or tailored lighting method
<i>Definition</i>	Custom lighting power covers lighting sources that are not included as general lighting. These include task lighting, display lighting and other specialized lighting designated in the footnotes to Table 140.6-C and lighting systems in Table 140.6-D of the Standards

This lighting must be entered separately from the general lighting because it is not subject to tradeoffs.

Software shall allow the user to input a custom lighting input for the allowed lighting system. Custom lighting power cannot be used with the complete building method. If area category method is used, custom lighting power cannot be used if the tailored method is used for any area of the building. See Table Lighting Specification Options for details.

<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	<p>Same as proposed, but subject to the maximum limits specified in the footnotes to Table 140.6-C and Table 140.6-D of the Standards. For spaces using the tailored method, the maximum allowed custom power is defined by the following procedure:</p> <p>Step 1. Find the Primary Function Area that matches the space type from Appendix A in Table 140.6-D.</p> <p>Step 2. Multiply the proposed wall display length times the applicable power in Column 3 of Table 140.6-D.</p> <p>Step 3. Multiply the applicable value in column 4 of Table 140.6-D times the floor area of the space.</p> <p>Step 4. Multiply the applicable value in column 5 of Table 140.6-D times the floor area of the space.</p> <p>Step 5. Add the lighting power (Watts) from steps 2, 3 and 4.</p> <p>Step 6. If the proposed custom lighting power is greater than the custom lighting power limit, then the standard design custom lighting power is set to the custom lighting power limit. Otherwise, if the proposed Custom Lighting Power is less than the custom lighting power limit, then the standard design Custom Lighting Power equals the proposed design custom lighting power.</p>
<i>Standard Design, Existing Buildings</i>	For alterations where less than 40 luminaires have been modified, the baseline is the existing lighting condition before the alteration. If 40 or more luminaires have been modified, the custom lighting power for the baseline is the same as proposed, but subject to the limits specified in the footnotes to Table 140.6-C of the Standards.

#### **Non-Regulated Interior Lighting Power**

<i>Applicability</i>	All projects
<i>Definition</i>	For California, §140.6(a)3 of the energy efficiency standards identifies non-regulated (exempted) lighting.
<i>Units</i>	W/ft <sup>2</sup> or Watts
<i>Input Restrictions</i>	As designed. The non-regulated lighting power should be cross-referenced to the type of exception and to the construction documents. The default for non-regulated lighting power is zero.
<i>Standard Design</i>	The non-regulated interior lighting in the baseline building shall be the same as the proposed design.
<i>Standard Design, Existing Buildings</i>	Same as proposed

**Lighting Schedules**

<i>Applicability</i>	All projects
<i>Definition</i>	Schedule of operation for interior lighting power used to adjust the energy use of lighting systems on an hourly basis to reflect time-dependent patterns of lighting usage. Different schedules may be defined for different lighting circuits, depending on the capabilities of the software.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The lighting schedule is prescribed for California Compliance and California Reach. An appropriate schedule from Appendix 5.4B shall be used.
<i>Standard Design</i>	The baseline building shall use the same lighting schedules as the proposed design.
<i>Standard Design, Existing Buildings</i>	Same as proposed

**Tailored Lighting Illumination Height**

<i>Applicability</i>	Spaces that have special tailored lighting power allowances
<i>Definition</i>	The illumination height is the vertical distance from the workplane to the luminaire. This is used in the calculation of the Room Cavity Ratio.
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as proposed. The baseline general lighting power for the space that uses the tailored lighting method is calculated by one of the following equations:

$$RCR = \frac{5 \times H \times (L + W)}{L \times W} \quad \text{for rectangular rooms}$$

$$RCR = \frac{2.5 \times H \times P}{A} \quad \text{for irregular-shaped rooms}$$

Where the illumination height defined for this input is H, the room length is L, width is W, perimeter is P and room area is A.

The allowed general lighting power for the tailored method is a function of the room cavity ratio and the space illumination level (in lux), and specified in Table 140.6-G of the Standards.

<i>Standard Design, Existing Buildings</i>	Same as for new construction
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**Light Heat Gain Distribution**

<i>Applicability</i>	All projects
<i>Definition</i>	The distribution of the heat generated by the lighting system that is directed to the space, the plenum, the HVAC return air, or to other locations. This input is a function of the luminaire type and location. Luminaires recessed into a return air plenum contribute more of their heat to the plenum or the return air stream if the plenum is

	used for return air; while pendant mounted fixtures hanging in the space contribute more of their heat to the space. Common luminaire type/space configurations are listed in Table 3, Chapter 18, 2009 ASHRAE Handbook of Fundamentals, summarized in Table 8 below. Typically the data will be linked to list of common luminaire configurations similar to Table 8 so that the user chooses a luminaire type category and heat gain is automatically distributed to the appropriate locations.
<i>Units</i>	List (of luminaire types) or data structure consisting of a series of decimal fractions that assign heat gain to various locations.
<i>Input Restrictions</i>	Default values listed in Table 8 shall be used as a default when the luminaire categories apply. Values within the ranges of Table 8 may be used when following the rules in the 2009 HOF. Other values may be used when manufacturers' literature and/or testing data is available, and adequate documentation is provided to the CEC.  Where lighting fixtures having different heat venting characteristics are used within a single space, the wattage weighted average heat-to-return-air fraction shall be used.
<i>Standard Design</i>	The baseline building shall use the above referenced defaults.
<i>Standard Design, Existing Buildings</i>	Same as for new construction

*Table 8 – Light Heat Gain Parameters for Typical Operating Conditions*

Source: 3, Table 3, Chapter 18, 2009 ASHRAE Handbook – Fundamentals

(ENTER ASHRAE TABLE HERE WITH ATTRIBUTION)

#### **Power Adjustment Factors (PAF)**

<i>Applicability</i>	All projects
<i>Definition</i>	<p>Automatic controls that are not already required by the baseline standard and which reduce lighting power more or less uniformly over the day can be modeled as power adjustment factors. Power adjustment factors represent the percent reduction in lighting power that will approximate the effect of the control. Models account for such controls by multiplying the controlled watts by <math>(1 - \text{PAF})</math>.</p> <p>Eligible California power adjustment factors are defined in Table 140.6-A. Reduction in lighting power using the PAF method can be used only for non-residential controlled general lights. Only one PAF can be used for a qualifying lighting system unless additions are allowed in Table 140.6.A of the standards. Controls for which PAFs are eligible are listed in Table 140.6-A of the California energy efficiency standards and include:</p> <ul style="list-style-type: none"> <li>• Occupancy Sensing Controls for qualifying enclosed spaces and open offices</li> <li>• Demand Control – Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal for qualifying building types.</li> <li>• Manual and multiscene programmable dimming for qualifying area types.</li> <li>• Manual Dimming plus multi-level occupancy sensor for qualifying area types.</li> </ul>
<i>Units</i>	List: eligible control types (see above) linked to PAFs
<i>Input Restrictions</i>	PAF shall be fixed for a given control and area type
<i>Standard Design</i>	PAF is zero
<i>Standard Design, Existing Buildings</i>	PAF is zero

### 5.4.4 Daylighting Control

This group of building descriptors is applicable for spaces that have daylighting controls or daylighting control requirements. Spaces that have daylighting should be defined separately from spaces that do not.

California prescribes a modified version of the split flux daylighting methods to be used for Compliance and Reach. This is an *internal daylighting method* because the calculations are automatically performed by the simulation engine. For top-lighted or sidelit daylighted areas, California Compliance prescribes an internal daylighting model consistent with the split flux algorithms used in many simulation programs. With this method the simulation model has the capability to model the daylighting contribution for each hour of the simulation and make an adjustment to the lighting power for each hour, taking into account factors such as daylighting availability, geometry of the space, daylighting aperture, control type and the lighting system. The assumption is that the geometry of the space, the reflectance of surfaces, the size and configuration of the daylight apertures, and the light transmission of the glazing are taken from other building descriptors.

#### Daylight Control Requirements

<i>Applicability</i>	All spaces with daylighting controls
<i>Definition</i>	The conditions that determine if daylighting has to be modeled in a space
<i>Units</i>	List
<i>Input Restrictions</i>	Primary Only, Primary and Secondary As designed
<i>Standard Design</i>	If the calculated general lighting power in the Secondary Daylight Zone is greater than 120 Watts, then the Standard design has <i>Primary and Secondary</i> daylight controls. Otherwise the daylight control is <i>Primary Only</i> .
<i>Standard Design, Existing Buildings</i>	When alterations include skylight replacement or addition and recirculation of existing general lighting system, the standard design will be same as new construction.

#### Skylit, Primary and Secondary Daylighted Area

<i>Applicability</i>	All daylighted spaces
<i>Definition</i>	<p>The floor area that is daylighted. The skylit area is the portion of the floor area that gets daylighting from a skylight. Two types of sidelit daylighted areas are recognized. The primary daylighted area is the portion that is closest to the daylighting source and receives the most illumination. The secondary daylighted area is an area farther from the daylighting source, but still receives useful daylight.</p> <p>The primary daylight area for sidelighting is a band near the window with a depth equal to the distance from the floor to the top of the window and width equal to window width plus 0.5 times window head height wide on each side of the window opening. The secondary daylight area for sidelighting is a band beyond the primary daylighted area that extends a distance double the distance from the floor to the top of the window and width equal to window width plus 0.5 times window head height wide on each side of the window opening. Area beyond a permanent obstruction taller than 6 feet should not be included in the primary and secondary daylight area calculation.</p> <p>The skylit area is a band around the skylight well that has a depth equal to the 70% of the ceiling height from the edge of the skylight well. The geometry of the skylit daylight area will be the same as the geometry of the skylight. Area beyond a permanent</p>

obstruction taller than 50% of the height of the skylight from the floor should not be included in the skylit area calculation.

Double counting due to overlaps is not permitted. If there is an overlap between Secondary and Primary or Skylit areas, the effective daylit area used for determining Reference position shall be the area minus the overlap.

<i>Units</i>	ft <sup>2</sup>
<i>Input Restrictions</i>	The daylit areas in a space is derived using other modeling inputs like dimensions of the fenestration and ceiling height of the space.
<i>Standard Design</i>	The daylit areas in the baseline building is derived from other modeling inputs like dimensions of the fenestration and ceiling height of the space. Daylit area calculation in the standard design is done after Window to wall ratio and Skylight to roof ratio rules in Section 5.5.7 of this manual are applied.
<i>Standard Design, Existing Buildings</i>	Same as new construction, when skylights are added or replaced and general lighting altered.

#### **Installed General Lighting Power in the Primary and Skylit Daylit Zone**

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The installed lighting power of general lighting in the primary and skylit daylit zone. The primary and skylit daylit zone shall be defined on the plans and be consistent with the definition of the primary and skylit daylit zone in the Standards. Note that a separate building descriptor, Fraction of Controlled Lighting, defines the fraction of the lighting power in the daylit zone that is controlled by daylighting.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	The Installed lighting power for the standard design is the product of the primary daylit area and the lighting power density (LPD) for general lighting in the space.
<i>Standard Design, Existing Buildings</i>	Same as new construction when skylights are added, replaced and general lights are altered.

#### **Installed General Lighting Power in the Secondary Daylit Zone**

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The installed lighting power of general lighting in the secondary daylit zone. The secondary daylit zone shall be defined on the plans and be consistent with the definition of the secondary daylit zone in the Standards. Note that a separate building descriptor, Fraction of Controlled Lighting, defines the fraction of the lighting power in the daylit zone that is controlled by daylighting.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	The Installed lighting power for the standard design is the product of the secondary daylit area and the lighting power density (LPD) for general lighting in the space.
<i>Standard Design, Existing Buildings</i>	Same as new construction when skylights are added, replaced and general lights are altered.

**Reference Position for Illuminance Calculations**

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	<p>The position of the daylight reference point within the daylighted space. Lighting controls are simulated so that the illuminance at the reference position is always equal to or above the illuminance setpoint. Thus for step switching controls, the combined daylight illuminance plus uncontrolled electric light illuminance at the reference position must be greater than the setpoint illuminance before the controlled stage of lighting can be tuned off. Similarly, dimming controls will be dimmed so that the combination of the daylight illuminance plus the controlled lighting illuminance is equal to the setpoint illuminance.</p> <p>Reference point for primary and secondary daylit areas is located at the farthest end of the daylit area at the center of the window. For skylit area, the reference point is located at the center of the edge of the skylit area. Up to two reference positions can be defined in a space.</p>
<i>Units</i>	Data structure
<i>Input Restrictions</i>	<p>The following steps shall be followed for determining the reference positions.</p> <ol style="list-style-type: none"> <li>1. Determine all non-overlapping daylit areas in a space. Double counting due to overlaps is not permitted. If there is an overlap between Secondary and Primary or Skylit areas, the effective daylit area used for determining Reference position shall be the area minus the overlap.</li> <li>2. Locate Reference position 1 in daylit space in following order of priority-             <ol style="list-style-type: none"> <li>a. Skylit area</li> <li>b. Primary daylit area in the South</li> <li>c. Primary daylit area in the West</li> <li>d. Primary daylit area in the East</li> <li>e. Primary daylit area in the North</li> </ol> </li> <li>3. Determine if the space has Secondary Daylit area and automatic controls are installed in the Secondary daylit area. If no, locate Reference position 2 in the next primary daylit space type in the order of priority described in the step 2. If yes, locate Reference point 2 in secondary daylit space in following order of priority:             <ol style="list-style-type: none"> <li>a. Secondary daylit area in the South</li> <li>b. Secondary daylit area in the West</li> <li>c. Secondary daylit area in the East</li> <li>d. Secondary daylit area in the North</li> </ol> </li> </ol> <p>For non-cardinal direction facing areas, the following orientation logic can be used:</p> <ol style="list-style-type: none"> <li>a. Windows facing between 315 degrees and 45 degrees -North</li> <li>b. Windows facing between 135 degrees and 45 degrees- East</li> <li>c. Windows facing between 135 degrees and 225 degrees – South</li> <li>d. Windows facing between 315 degrees and 225 degrees – West.</li> </ol>
<i>Standard Design</i>	<p>The following steps shall be followed for determining the reference positions.</p> <ol style="list-style-type: none"> <li>1. Determine all non-overlapping daylit areas in a space. Double counting due to overlaps is not permitted. If there is an overlap between Secondary and Primary or Skylit areas, the effective daylit area used for determining Reference position shall be the area minus the overlap.</li> <li>2. Locate Reference position 1 in daylit space in following order of priority-             <ol style="list-style-type: none"> <li>a. Skylit area</li> <li>b. Primary daylit area in the South</li> </ol> </li> </ol>

- c. Primary daylit area in the West
- d. Primary daylit area in the East
- e. Primary daylit area in the North

3. Determine if the space has Secondary Daylit area. If no, locate Reference position 2 in the next primary daylit space type in the order of priority described in the step 2. If yes, locate Reference point 2 in secondary daylit space in following order of priority:

- a. Secondary daylit area in the South
- b. Secondary daylit area in the West
- c. Secondary daylit area in the East
- d. Secondary daylit area in the North

For non-cardinal direction facing areas, the following orientation logic can be used:

- a. Windows facing between 315 degrees and 45 degrees -North
- b. Windows facing between 135 degrees and 45 degrees- East
- c. Windows facing between 135 degrees and 225 degrees – South
- d. Windows facing between 315 degrees and 225 degrees – West.

<i>Standard Design,</i>	Same as new construction, when skylights are added or replaced and general lighting altered
<i>Existing Buildings</i>	

#### **Daylight Illuminance Setpoint**

<i>Applicability</i>	Daylit spaces
<i>Definition</i>	The design illuminance for the daylit space for purposes of daylighting control.
<i>Units</i>	lux
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	<p>The standard design illuminance setpoint is defined for each space type in Appendix 5.4A (in lux). The baseline daylight illuminance setpoint is the same as proposed design, unless a range is specified for the space type in Appendix 5.4A.</p> <p>Where a range is defined in the Appendix, the standard design setpoint is:</p> <ol style="list-style-type: none"> <li>1. If the proposed design illuminance setpoint is higher than the high point of the range in Appendix 5.4A, then the standard design setpoint is the high point of the range.</li> <li>2. If the proposed design illuminance setpoint is within the range of illuminance setpoints specified in Appendix 5.4A, then the standard design setpoint is the same as the proposed.</li> <li>3. If the proposed design illuminance setpoint is below the range of setpoints specified in Appendix 5.4A for the given space type, then the standard design setpoint shall be same as proposed. In this case an Exceptional Condition may be reported on the compliance documentation.</li> </ol>
<i>Standard Design,</i> <i>Existing Buildings</i>	Same as for new construction, when skylights are added, replaced and general lighting altered.

#### **Illumination Adjustment Factor**

<i>Applicability</i>	All daylighted spaces
<i>Definition</i>	

Recent studies have shown that the split flux interreflection component model used in many simulation programs overestimates the energy savings due to daylighting, particularly deep in the space. A set of two adjustment factors is provided, one for the primary daylit zone and one for the secondary daylit zone.

For simulation purposes, the input daylight illuminance setpoint will be modified by the Illuminance Adjustment factor as follows:

$$\text{LIGHT-SET-PT}_{\text{adj}} = \text{LIGHT-SET-PT} \times \text{Adjustment Factor}$$

<i>Units</i>	unitless
<i>Input Restrictions</i>	As per prescribed values for space type in Appendix 5.4A Spaces with no furniture ; Fixed at the following values: Primary Daylit Zone:1.5 Secondary Daylit Zone:2.0 Spaces with furniture ; Primary Daylit Zone: 1.0 Secondary Daylit Zone: 4.0
<i>Standard Design</i>	The baseline building adjustment factors shall match the proposed.
<i>Standard Design, Existing and Altered</i>	Same as for new construction, when skylights are added, replaced and general light altered.

#### Fraction of Controlled Lighting

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The fraction of the general lighting power in the daylighted space that is controlled by daylighting controls.
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed for secondary daylit areas. If the proposed design has no daylight controls in the secondary daylit area the value is set to 0 for the general lights in the secondary daylit area. Primary and skylit daylit area fraction of controlled general lighting shall be 1.
<i>Standard Design</i>	Daylighting controls are required for skylighted and primary and secondary daylight areas. The fraction of controlled general lighting shall be 1.
<i>Standard Design, Existing Buildings</i>	Same as new construction when skylights are added, replaced and general lights are altered.

#### Daylighting Control Type

<i>Applicability</i>	Daylighted spaces.
<i>Definition</i>	The type of control that is used to control the electric lighting in response to daylight available at the reference point. The options are:

- Step Dimming controls have discrete steps of light output but typically the intermediate steps of light output are associated with higher levels of fraction of rated power. When the lights are fully off or fully on, the fraction of rated power matches the fraction of light output. Stepped Controls vary the electric input power and lighting output power in discrete equally spaced steps. See Figure 4 – Example Stepped Daylight Control.
- Continuous Dimming controls have a fraction to rated power to fraction of rated output that is a linear interpolation of the *minimum power fraction* at the *minimum dimming light fraction* to rated power (power fraction = 1.0) at full light output. See Figure 5.
- Continuous Dimming + Off controls are the same as continuous dimming controls except that these controls can turn all the way off when none of the controlled light output is needed. See Figure 5.

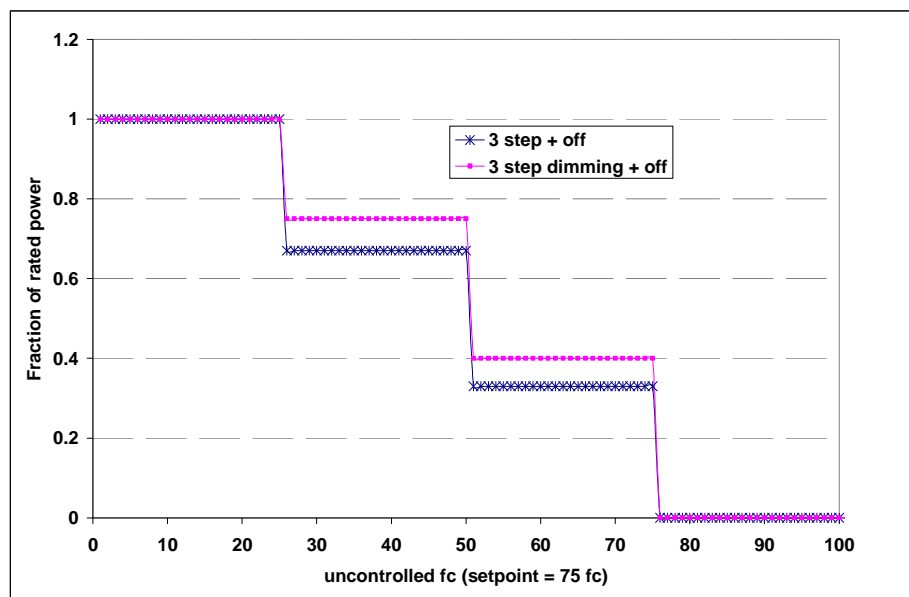


Figure 4 – Example Stepped Daylight Control

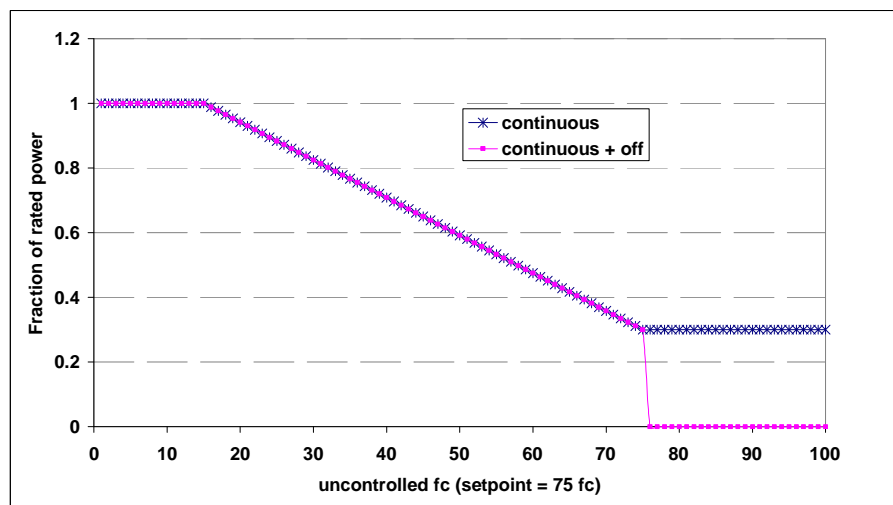


Figure 5 – Example Dimming Daylight Control

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Continuous
<i>Standard Design, Existing Buildings</i>	Same as for new construction, when skylights are added, replaced and general lighting altered.

**Minimum Dimming Power Fraction**

<i>Applicability</i>	Daylit spaces
<i>Definition</i>	The minimum power fraction when controlled lighting is fully dimmed. Minimum power fraction = (Minimum power) / (Full rated power). See Figure 5.
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Baseline building uses continuous dimming control with a minimum dimming power fraction of : LED: 0.1 Linear Fluorescent: 0.2 CFL: 0.3 Metal Halide: TBD Where the Controlled Luminaire Type, input by the user, determines the Minimum Dimming Power Fraction
<i>Standard Design Existing Buildings</i>	Same as for new construction, when skylights are added, replaced and general lighting altered

**Minimum Dimming Light Fraction**

<i>Applicability</i>	Daylighted and dimming controls
<i>Definition</i>	Minimum light output of controlled lighting when fully dimmed. Minimum light fraction = (Minimum light output) / (Rated light output). See Figure 5.
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Baseline building uses continuous dimming control with a minimum dimming light fraction of : LED: TBD Linear Fluorescent: TBD CFL: TBD Metal Halide: TBD Where the Controlled Luminaire Type, input by the user, determines the Minimum Dimming Power Fraction

*Standard Design, Existing Buildings* Same as for new construction, when skylights are added, replaced and general lighting altered

#### **Number of Control Steps**

*Applicability* Daylighted spaces that use stepped controls

*Definition* Number of control steps- For step dimming, identifies number of steps that require fraction of rated light output and rated power fraction.

*Units* Numeric: integer

*Input Restrictions* Integer 1 or 4 for primary and skylit daylight areas, as designed for secondary daylight areas .

*Standard Design* Not applicable.

*Standard Design, Existing Buildings* Same as for new construction, when skylights are added, replaced and general lighting altered

#### **Controlled Luminaire Type**

*Applicability* Daylit spaces

*Definition* The predominant luminaire type in the daylight control zone. This is defined as the type of luminaire that has the most installed wattage in the daylight control zone. This input defines which dimming curve to use (from a lookup table)

*Units* List (TBD)

Metal halide

Compact fluorescent

Linear fluorescent

LED

*Input Restrictions* As designed

*Standard Design* Same as proposed

### **5.4.5 Receptacle Loads**

Receptacle loads contribute to heat gains in spaces and directly use energy.

#### **Receptacle Power**

*Applicability* All building projects

*Definition* Receptacle power is power for typical general service loads in the building. Receptacle power includes equipment loads normally served through electrical receptacles, such as office equipment and printers, but does not include either task lighting or equipment used for HVAC purposes. Receptacle power values are slightly higher than the largest hourly receptacle load that is actually modeled because the receptacle power values are modified by the receptacle schedule, which approaches but does not exceed 1.0.

Receptacle power is considered an unregulated load; no credit has been offered in the past for savings; identical conditions have been required for both the baseline building

	and the proposed design. Offering credit for receptacle loads is very difficult due to their temporal nature and because information is not always available on what equipment will go in the building. Tenants also have the ability to plug and unplug devices at their leisure or switch them out for different equipment, adding to the difficulty of assigning credit for promised energy efficiency.
<i>Units</i>	Total power (W) or the space or power density (W/ft <sup>2</sup> )  The receptacle power in the baseline building shall be the same as the proposed design.
<i>Input Restrictions</i>	For California Compliance and California Reach, values from Appendix 5.4A shall be used as a default value. If values other than those shown in Appendix 5.4A are used, this will be reported as a condition requiring an Exceptional Condition Review by a third party reviewer
<i>Standard Design</i>	Same as Proposed
<i>Standard Design, Existing Buildings</i>	Same as for new construction

#### Receptacle Schedule

<i>Applicability</i>	All projects
<i>Definition</i>	Schedule for receptacle power loads used to adjust the intensity on an hourly basis to reflect time-dependent patterns of usage.
<i>Units</i>	Data structure: schedule, fraction
<i>Input Restrictions</i>	For compliance and Reach, the schedule is prescribed in appendix 5.4A. If values other than those shown in Appendix 5.4A are used, this will be reported as a condition requiring an Exceptional Condition Review by a third party reviewer.
<i>Standard Design</i>	Schedules for the baseline building shall be identical to the proposed design.
<i>Standard Design, Existing Buildings</i>	Same as for new construction

### 5.4.6 Commercial Refrigeration Equipment

Commercial refrigeration equipment includes the following:

- Walk-in refrigerators
- Walk-in freezers
- Refrigerated casework

Walk-in refrigerators and freezers typically have remote condensers. Some refrigerated casework has remote condensers, while some have a self-contained condenser built into the unit. Refrigerated casework with built-in condensers rejects heat directly to the space while remote condensers reject heat in the remote location, typically on the roof or behind the building.

Refrigerated casework can be further classified by the purpose, the type of doors and, when there are no doors, the configuration: horizontal, vertical or semi-vertical. USDOE has developed standards for refrigerated casework. Table 9 shows these classifications along with the standard level of performance,

expressed in kWh/d, which depends on the class of equipment, the total display area, and the volume of the casework.

Table 9 – USDOE Requirements for Refrigerated Casework (kWh/d)

TABLE I-1—STANDARD LEVELS FOR COMMERCIAL REFRIGERATION EQUIPMENT

Equipment class <sup>2</sup>	Standard level <sup>***</sup> (kWh/day)	Equipment class	Standard level <sup>***</sup> (kWh/day)
VOP.RC.M	$0.82 \times \text{TDA} + 4.07$	VCT.RC.I	$0.66 \times \text{TDA} + 3.05$
SVO.RC.M	$0.83 \times \text{TDA} + 3.18$	HCT.RC.M	$0.16 \times \text{TDA} + 0.13$
HZO.RC.M	$0.35 \times \text{TDA} + 2.88$	HCT.RC.L	$0.34 \times \text{TDA} + 0.26$
VOP.RC.L	$2.27 \times \text{TDA} + 6.85$	HCT.RC.I	$0.4 \times \text{TDA} + 0.31$
HZO.RC.L	$0.57 \times \text{TDA} + 6.88$	VCS.RC.M	$0.11 \times \text{V} + 0.26$
VCT.RC.M	$0.22 \times \text{TDA} + 1.95$	VCS.RC.L	$0.23 \times \text{V} + 0.54$
VCT.RC.L	$0.56 \times \text{TDA} + 2.61$	VCS.RC.I	$0.27 \times \text{V} + 0.63$
SOC.RC.M	$0.51 \times \text{TDA} + 0.11$	HCS.RC.M	$0.11 \times \text{V} + 0.26$
VOP.SC.M	$1.74 \times \text{TDA} + 4.71$	HCS.RC.L	$0.23 \times \text{V} + 0.54$
SVO.SC.M	$1.73 \times \text{TDA} + 4.59$	HCS.RC.I	$0.27 \times \text{V} + 0.63$
HZO.SC.M	$0.77 \times \text{TDA} + 5.55$	SOC.RC.L	$1.08 \times \text{TDA} + 0.22$
HZO.SC.L	$1.92 \times \text{TDA} + 7.08$	SOC.RC.I	$1.26 \times \text{TDA} + 0.26$
VCT.SC.I	$0.67 \times \text{TDA} + 3.29$	VOP.SC.L	$4.37 \times \text{TDA} + 11.82$
VCS.SC.I	$0.38 \times \text{V} + 0.88$	VOP.SC.I	$5.55 \times \text{TDA} + 15.02$
HCT.SC.I	$0.56 \times \text{TDA} + 0.43$	SVO.SC.L	$4.34 \times \text{TDA} + 11.51$
SVO.RC.L	$2.27 \times \text{TDA} + 6.85$	SVO.SC.I	$5.52 \times \text{TDA} + 14.63$
VOP.RC.I	$2.89 \times \text{TDA} + 8.7$	HZO.SC.I	$2.44 \times \text{TDA} + 9$
SVO.RC.I	$2.89 \times \text{TDA} + 8.7$	SOC.SC.I	$1.76 \times \text{TDA} + 0.36$
HZO.RC.I	$0.72 \times \text{TDA} + 8.74$	HCS.SC.I	$0.38 \times \text{V} + 0.88$

\* TDA is the total display area of the case, as measured in the Air-Conditioning and Refrigeration Institute (ARI) Standard 1200–2006, Appendix D.

\*\* V is the volume of the case, as measured in ARI Standard 1200–2006, Appendix C.

\*\*\* Kilowatt hours per day.

<sup>2</sup> For this rulemaking, equipment class designations consist of a combination (in sequential order separated by periods) of: (1) An equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter); (2) an operating mode code (RC=remote condensing or SC=self contained); and (3) a rating temperature code (M=medium temperature (38 °F), L=low temperature (0 °F), or I=ice-cream temperature (–15 °F)). For example, “VOP.RC.M” refers to the “vertical open, remote condensing, medium temperature” equipment class. See discussion in section V.A.2 and chapter 3 of the TSD, market and technology assessment, for a more detailed explanation of the equipment class terminology. See Table IV–2 for a list of the equipment classes by category.

Walk-in refrigerators and freezers are not covered by the USDOE standards and test procedures. Title-24 default values for these are given in Table 10. These values are expressed in W/ft<sup>2</sup> of refrigerator or freezer area. This power is assumed to occur continuously. Some walk-ins have glass display doors on one side so that products can be loaded from the back. Glass display doors increase the power requirements of walk-ins. Additional power is added when glass display doors are present. The total power for walk-in refrigerators and freezers is given in Equation (1).

(1)

$$P_{Walk-in} = (A_{Ref} \cdot PD_{Ref} + N_{Ref} \cdot D_{Ref}) + (A_{Frz} \cdot PD_{Frz} + N_{Frz} \cdot D_{Frz})$$

Where

$P_{Walk-in}$  is the estimated power density for the walk-in refrigerator or freezer in (W)

$A_{xxx}$  the area of the walk-in refrigerator or freezer (ft<sup>2</sup>)

$N_{xxx}$  the number of glass display doors (unitless)

$PD_{xxx}$  the power density of the walk-in refrigerator or freezer taken from Table 10 (W/ft<sup>2</sup>)

$D_{xxx}$  the power associated with a glass display door for a walk-in refrigerator or freezer (W/door)

xxx subscript indicating a walk-in freezer or refrigerator (Ref or Frz)

**Table 10 – Default Power for Walk-In Refrigerators and Freezers (W/ft²)**

Source: These values are determined using the procedures of the Heatcraft Engineering Manual, Commercial Refrigeration Cooling and Freezing Load Calculations and Reference Guide, August 2006. The EER is assumed to be 12.39 for refrigerators and 6.33 for Freezers. The specific efficiency is assumed to be 70 for refrigerators and 50 for freezers. Operating temperature is assumed to be 35 F for refrigerators and -10 F for freezers.

Floor Area	Refrigerator	Freezer
100 ft² or less	8.0	16.0
101 ft² to 250 ft²	6.0	12.0
251 ft² to 450 ft²	5.0	9.5
451 ft² to 650 ft²	4.5	8.0
651 ft² to 800 ft²	4.0	7.0
801 ft² to 1,000 ft²	3.5	6.5
More than 1,000 ft²	3.0	6.0
Additional Power for each Glass Display Door	105	325
Note:		

### Refrigeration Modeling Method

<b>Applicability</b>	All buildings that have commercial refrigeration for cold storage or display
<b>Definition</b>	<p>The method used to estimate refrigeration energy and to model the thermal interaction with the space where casework is located. Two methods are included in this manual:</p> <ul style="list-style-type: none"> <li>• <b>Title 24 defaults.</b> With this method, the power density values provided in Appendix 5.4A<sup>1</sup> are used; schedules are assumed to be continuous operation.</li> <li>• <b>USDOE performance ratings.</b> With this method, the energy modeler takes inventory of the refrigerated casework in the rated building and sums the rated energy use (typically in kWh/day). Walk-in refrigerators and freezers shall use the defaults from Equation (1) and the values from Table 10. All refrigeration equipment is then assumed to operate continuously.</li> </ul> <p>The remaining building descriptors in this section apply to buildings that use either the Title-24 defaults or the USDOE performance ratings.</p>
<b>Units</b>	List (see above)
<b>Input Restrictions</b>	For California Compliance, the <i>Title 24 defaults</i> shall be used. Otherwise, there are no input restrictions.
<b>Standard Design</b>	Same as proposed

<sup>1</sup> See Table C-43, p. 146 of NREL/TP-550-41956, Methodology for Modeling Building Energy Performance across the Commercial Sector, Technical Report, Appendix C, March 2008. The values in this report were taken from Table 8-3 of the California Commercial End-Use Survey, Consultants Report, March 2006, CEC-400-2006-005

Standard Design, Existing Buildings Same as for new construction

### Refrigeration Power

Applicability	All buildings or spaces that have commercial refrigeration for cold storage or display.
Definition	Commercial refrigeration power is the average power for all commercial refrigeration equipment, assuming constant year-round operation. Equipment includes walk-in refrigerators and freezers, open refrigerated casework, and closed refrigerated casework. It does not include residential type refrigerators used in kitchenettes or refrigerated vending machines. These are covered under <i>receptacle power</i> .
Units	W/ft <sup>2</sup>
Input Restrictions	With the <i>Title 24 defaults</i> method, the values in Appendix 5.4A are prescribed. These values are multiplied times the floor area of the rated building to estimate the refrigeration power. With the <i>USDOE performance ratings</i> method, refrigeration power is estimated by summing the kWh/day for all the refrigeration equipment in the space and dividing by 24 hours. The refrigeration power for walk-in refrigerators and freezers is added to this value.
Standard Design	Refrigeration power is the same as the proposed design when the Title 24 defaults are used. When the <i>USDOE performance ratings</i> method is used, refrigeration power for casework shall be determined from Table 9; the power for walk-in refrigerators and freezers shall be the same as the proposed design.
Standard Design, Existing Buildings	Same as for new construction

### Remote Condenser Fraction

Applicability	All buildings that have commercial refrigeration for cold storage or display and use the <i>Title 24 defaults</i> or <i>USDOE performance ratings</i> methods
Definition	<p>The fraction of condenser heat that is rejected to the outdoors. For self-contained refrigeration casework, this value will be zero. For remote condenser systems, this value is 1.0. For combination systems, the value should be weighted according to refrigeration capacity.</p> <p>For refrigeration with self-contained condensers and compressors, the heat that is removed from the space is equal to the heat that is rejected to the space, since the evaporator and condenser are both located in the same space. There may be some latent cooling associated with operation of the equipment, but this may be ignored with the <i>Title 24 defaults</i> or <i>USDOE performance ratings</i> methods. The operation of self-contained refrigeration units may be approximated by adding a continuously operating electric load to the space that is equal to the energy consumption of the refrigeration units. Self-contained refrigeration units add heat to the space that must be removed by the HVAC system.</p> <p>When the condenser is remotely located, heat is removed from the space but rejected outdoors. In this case, the refrigeration equipment functions in a manner similar to a continuously running split system air conditioner. Some heat is added to the space for the evaporator fan, the anti-fog heaters and other auxiliary energy uses, but refrigeration systems with remote condensers remove more heat from the space where they are located than they add. The HVAC system must compensate for this imbalance.</p>

For remotely located condensers using the *Title 24 defaults* or *USDOE performance ratings* methods, the heat that is removed from the space is determined as follows:

(2)

$$Q = [(1 - F) \times kW - (F \times kW \times COP)] \times 3.413$$

Where

Q	The rate of heat removal from the space due to the continuous operation of the refrigeration system (kBtu/h). A negative number means that heat is being removed from the space; a positive number means that heat is being added.
kW	The power of the refrigeration system determined by using the <i>Title 24 defaults</i> or the <i>USDOE performance ratings</i> method (kW)
F	The remote condenser fraction (see building descriptor below) (unitless)
COP	The coefficient of performance of the refrigeration system (unitless)

The simple approach outlined above assumes that there is no latent cooling associated with the refrigeration system. The heat addition or removal resulting from the above equation can be modeled in a number of ways, to accommodate the variety of calculation engines available. It can be scheduled if the engine can accommodate a heat removal schedule. It can be modeled as a separate, constantly running air conditioner, if the engine can accommodate two cooling systems serving the same thermal zone. Other modeling techniques are acceptable as long as they are thermodynamically equivalent.

<i>Units</i>	Fraction
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Same as for new construction

### Refrigeration COP

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display and use the <i>Title 24 defaults</i> or <i>USDOE performance ratings</i> methods
<i>Definition</i>	

	The coefficient of performance of the refrigeration system. This is used only to determine the heat removed or added to the space, not to determine the refrigeration power or energy.
<i>Units</i>	Fraction
<i>Input Restrictions</i>	This value is prescribed to be 3.6 for refrigerators and 1.8 for freezers. <sup>2</sup>
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Same as for new construction

#### Refrigeration Schedule

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display
<i>Definition</i>	The schedule of operation for commercial refrigeration equipment. This is used to convert refrigeration power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Continuous operation is prescribed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Same as for new construction

### 5.4.7 Elevators, Escalators and Moving Walkways

Elevators, escalators and moving walkways account for 3% to 5% of electric energy use in buildings.<sup>3</sup> Buildings up to about five to seven stories typically use hydraulic elevators because of their lower initial cost. Mid-rise buildings commonly use traction elevators with geared motors, while high-rise buildings typically use gearless systems where the motor directly drives the sheave. The energy using components include the motors and controls as well as the lighting and ventilation systems for the cabs.

Elevators are custom designed for each building. In this respect they are less like products than they are engineered systems, e.g. they are more akin to chilled water plants where the engineer chooses a chiller, a tower, pumping and other components which are field engineered into a system. The main design criteria are safety and service. Some manufacturers have focused on energy efficiency of late and

<sup>2</sup> These values are consistent with the assumptions for the default values for walk-ins, which assume an EER of 12.39 for refrigerators and 6.33 for freezers.

<sup>3</sup> Sachs, Harvey M., Opportunities for Elevator Energy Efficiency Improvements, American Council for an Energy Efficiency Economy, April 2005

introduced technologies such as advanced controls that optimize the position of cars for minimum travel and regeneration motors that become generators when a loaded car descends or an empty car rises. These technologies can result in 35% to 40% savings.<sup>4</sup>

The motors and energy using equipment is typically located within the building envelope so it produces heat that must be removed by ventilation or by air conditioning systems. In energy models, a dedicated thermal zone (elevator shaft) will typically be created and this space can be indirectly cooled (from adjacent spaces) or positively cooled.

Little information is known on how to model elevators. As engineered systems, the model would need information on the number of starts per day, the number of floors, motor and drive characteristics, and other factors. Some work has been done to develop and categorize energy models for elevators;<sup>5</sup> however a simple procedure is recommended based on a count of the number of elevators, escalators and moving walkways in the building. This data is shown in Table 11.<sup>6</sup>

*Table 11 – Unit Energy Consumption Data for Elevators, Escalators and Moving Walkways<sup>7</sup>*

Mode	Elevators		Escalators and Moving Walkways	
	Power (W)	Annual Hours	Power (W)	Annual Hours
Active	10,000	300	4,671	4,380
Ready	500	7,365	n.a.	0
Standby	250	1,095	n.a.	0
Off	0	0	0	4,380
Typical Annual Energy Use	7,000 kWh/y		20,500 kWh/y	

#### **Elevator/Escalator Power**

<i>Applicability</i>	All buildings that have commercial elevators, escalator, or moving walkways
<i>Definition</i>	The power for elevators, escalators and moving walkways for different modes of operation. Elevators typically operate in three modes: active (when the car is moving passengers), ready (when the lighting and ventilation systems are active but the car is not moving), and standby (when the lights and ventilation systems are off). Escalators and moving walkways are either active or turned off.

*Units*

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<sup>4</sup> Ibid.

<sup>5</sup> Al-Sharif, Lutfi, Richard Peters and Rory Smith, Elevator Energy Simulation Model, Elevator World, November 2005, Volume LII, No11

<sup>6</sup> TIAx, Commercial and Residential Sector Miscellaneous Electricity consumption: Y20005 and Projections to 2030, Final Report to the U.S. Department of Energy's Energy Information Administration (EIA) and Decision Analysis Corporation (DAC), September 22, 2006, Reference Number D0366.

<sup>7</sup> The TIAx report does not give energy consumption data for moving walkways. For the purposes of this manual, it is assumed to be equal to escalators.

	W/unit
<i>Input Restrictions</i>	The power values from Table 11 for different modes of operation are prescribed for the proposed design.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### **Elevator/Escalator Schedule**

<i>Applicability</i>	All buildings that have commercial elevators, escalator, or moving walkways
<i>Definition</i>	The schedule of operation for elevators, escalators, and moving walkways. This is used to convert elevator/escalator power to energy use.
<i>Units</i>	Data structure: schedule, state
<i>Input Restrictions Standard Design</i>	The operating schedule is prescribed for California Compliance and Reach. For California Compliance, an appropriate schedule from Appendix 5.4B shall be used. If values other than those shown in Appendix 5.4B are used, this will be reported as a condition requiring an Exceptional Condition Review by a third party reviewer
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

### **5.4.8 Process, Gas**

Commercial gas equipment includes the following:

- Ovens
- Fryers
- Grills
- Other equipment

The majority of gas equipment is located in the space and may contribute both sensible and latent heat. Gas equipment is typically modeled by specifying the rate of peak gas consumption and modifying this with a fractional schedule. Energy consumption data for gas equipment is only beginning to emerge.

Because of these limits, the procedure for commercial gas is limited. The procedure consists of prescribed power and energy values for use with both the proposed design and the baseline building. No credit for commercial gas energy efficiency features is offered.

The prescribed values are provided in Appendix 5.4A. Schedules are defaulted to be continuous operation.

#### **Gas Equipment Power**

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	Commercial gas power is the average power for all commercial gas equipment, assuming constant year-round operation.

<i>Units</i>	Btu/h-ft <sup>2</sup>
<i>Input Restrictions</i>	The values in Appendix 5.4A are prescribed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### **Gas Equipment Schedule**

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The schedule of operation for commercial gas equipment. This is used to convert gas power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Continuous operation is prescribed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### **Gas Equipment Location**

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The assumed location of the gas equipment for modeling purposes. Choices are in the space or external.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### **Radiation Factor**

<i>Applicability</i>	Gas appliances located in the space
<i>Definition</i>	The fraction of heat gain to appliance energy use
<i>Units</i>	Fraction
<i>Input Restrictions</i>	Default value is 0.15. Other values can be used when a detailed inventory of equipment is known. The override value shall be based on data in Table 5C, Chapter 18, ASHRAE HOF, 2009, or similar tested information from the manufacturer.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### **Usage Factor**

<i>Applicability</i>	Gas appliances located in the space
<i>Definition</i>	A duty cycle or usage factor to appliance energy use

The radiation factor and usage factor are used together to determine the sensible heat gain to the space:

$$Q_{\text{sens}} = Q_{\text{input}} \times F_U \times F_R$$

Where  $Q_{\text{input}}$  is the heat input of the equipment in Btu/h or Btu/h-ft<sup>2</sup>,

$F_U$  is the usage factor and

$F_R$  is the radiation factor

*Units* Fraction

*Input Restrictions* Default value is 0.70. Other values can be used when a detailed inventory of equipment is known. The override value shall be based on data in Table 5C, Chapter 18, ASHRAE HOF, 2009, or similar tested information from the manufacturer.

*Standard Design* Same as the proposed design

*Standard Design,  
Existing Buildings* Not applicable

### Process Loads

*Applicability* Spaces with process loads

*Definition* Process load is the internal energy of a building resulting from an activity or treatment not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy. Process load may include sensible and/or latent components

Data centers loads including transformers, UPS, PDU, server fans and power supplies are considered receptacle loads, not process loads, and the equipment schedules are given in Appendix 5.4B.

Compliance software shall model and simulate process loads only if the amount of the process energy and the location and type of process equipment are specified in the construction documents. This information shall correspond to specific special equipment shown on the building plans and detailed in the specifications. The compliance software Compliance Documentation shall inform the user that the compliance software will output process loads including the types of process equipment and locations on the compliance forms.

*Units* Data structure: sensible (Btu/h), latent (Btu/h)

*Input Restrictions* Compliance software shall receive input for Sensible and/or Latent Process Load for each zone in the proposed design. The process load input shall include the amount of the process load (Btu/h-ft<sup>2</sup>) and the HVAC zone where the process equipment is located. The modeled information shall be consistent with the plans and specifications of the building.

*Standard Design* The standard design shall use the same process loads for each zone as the proposed design.

*Standard Design,  
Existing Buildings* Same as for new construction

### Process Load Schedule

*Applicability* All buildings that have commercial gas equipment

*Definition* The schedule of operation process load. This is used to convert gas power to energy

	use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

#### Process Load Location

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The assumed location of process load for modeling purposes. Choices are in the space or external.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Same as the proposed design
<i>Standard Design, Existing Buildings</i>	Not applicable

## 5.5 Building Envelope Data

### 5.5.1 Materials

Energy simulation programs commonly define construction assemblies by listing a sequence of material layers that make up the construction assembly. Typical construction assemblies and their respective material layers are defined in Reference Appendix JA4. Additionally, the properties of the each material layer can be found in ACM Appendix 5.5A.

#### Material Name

<i>Applicability</i>	When construction assemblies reference materials that are not standard
<i>Definition</i>	The name of a construction material used in the exterior envelope of the building
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	Material name is a required input for materials not available from the standard list in ACM Appendix 5.5A. The user may not modify entries for predefined materials.
<i>Standard Design</i>	Not applicable

#### Density

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The density (or mass per unit of volume) of the construction material as documented in an ASHRAE handbook, a comparably reliable reference, or manufacturers' literature.
<i>Units</i>	lb/ft <sup>3</sup>
<i>Input Restrictions</i>	

	Density is a required input when non-standard materials are specified.
<i>Standard Design</i>	Not applicable

**Specific Heat**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The specific heat capacity of a material is numerically equal to the quantity of heat that must be supplied to a unit mass of the material to increase its temperature by 1 °F
<i>Units</i>	Btu/lb.°F
<i>Input Restrictions</i>	Specific heat is a required input when non-standard materials are specified. The specific heat capacity of the construction material as documented in an ASHRAE handbook, a comparably reliable reference, or manufacturers' literature.
<i>Standard Design</i>	Not applicable

**Thermal Conductivity**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The thermal conductivity of a material of unit thickness is numerically equal to the quantity of heat that will flow through a unit area of the material when the temperature difference through the material is 1 °F.
<i>Units</i>	Btu/h·ft.°F
<i>Input Restrictions</i>	Thermal conductivity is a required input for non-standard materials.
<i>Standard Design</i>	Not applicable

**Thickness**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The thickness of a material
<i>Units</i>	ft or in.
<i>Input Restrictions</i>	Thickness is a required input for non-standard materials. The user shall document the data source for thermal conductivity used for additional materials under the <i>material name</i> descriptor.
<i>Standard Design</i>	Not applicable

**Reflectance**

<i>Applicability</i>	All opaque exterior surfaces exposed to ambient conditions; this is fixed for exterior walls at 0.3 and is the as-designed value entered for roofs, with some restrictions.
<i>Definition</i>	The solar reflectance of a material. For roofing materials, the 3-year aged reflectance value from CRRC testing should be used if available.
<i>Units</i>	Unitless fraction between 0 and 1
<i>Input Restrictions</i>	For new construction, if asphalt shingles or composition shingles are not rated by the Cool Roof Rating Council (CRRC), the default aged solar reflectance and emittance must be equal to or more efficient than the mandatory requirements in Section 110.8

of the Standards. The default value may be overridden when roof materials are used that have been tested by the (CRRRC) and are called for in the construction documents. In cases where the default value is overridden, the user is required to submit documentation identifying the test procedure that was used to establish the non-default values. If the aged reflectance is not known, the aged reflectance may be calculated from the initial reflectance by the following equation:

$$p_{\text{aged}} = 0.2 + \beta \cdot (p_{\text{init}} - 0.2)$$

Where,

$p_{\text{aged}}$  = the calculated aged reflectance

$\beta$  = 0.65 for field-applied coatings, 0.7 for all other roof surfaces

$p_{\text{nit}}$  = the initial reflectance

#### Standard Design

For new construction, the standard design reflectance shall meet the requirements stated in Section 140.3 of the Standards. Thermal emittance shall be 0.85.

For alterations to more than 50% of the roof area or roof areas above 2,000 ft<sup>2</sup> the standard design shall be modeled as the more efficient of either the existing conditions or the values required for cool roofs under Section 141.0 of the Standards. The roughness shall be set to the same value as the proposed design.

**SPECIAL NOTE: A SIMPLIFIED VERSION OF THE COMPLIANCE SOFTWARE WILL BE DEVELOPED TO BE USED FOR ENVELOPE TRADEOFFS, AND FOR ROOF ALTERATIONS IN PARTICULAR. THIS OPTION WILL CONSTRAIN ALMOST ALL INPUTS NOT RELATED TO ROOF PERFORMANCE AND WILL PROVIDE A WAY TO DETERMINE INSULATION TRADEOFFS ALLOWED WITH ROOF REFLECTANCE.**

## 5.5.2 Construction Assemblies

For California Compliance and Reach, construction assemblies for the proposed design shall be created by selecting from a library of building construction layers in ACM Appendix 5.5A. Choices from Reference Appendix JA4 are specified for the standard design building in ACM Appendix 5.5C. When a choice is made, all properties of the proposed design construction assembly are set, except as specified in this manual. The materials and layers that make up the construction assemblies are documented in the notes section of each table in Reference Appendix JA4. The choice from Reference Appendix JA4 also determines the construction of the standard design, according to the mappings shown in ACM Appendix 5.5C.

### Geometry

The geometry of roofs, walls, floors, doors and fenestration should match the construction documents or as-built drawings as accurately as possible. Unusual curved surfaces such as a dome or semi circular wall may be approximated by a series of constructions.

### Mass Walls

For mass walls, the user first chooses the mass layer from either Tables 4.3.5 or 4.3.6 of Reference Appendix JA4. After that, the user may select an insulating layer from Table 4.3.7 for outside and/or inside the mass wall. Up to three choices may be selected from Reference Appendix JA4.

### Ballasted Roofs, Vegetated Roofs, Concrete Pavers, and Other Mass Roofs

An additional layer may be added to the construction assembly specified in Reference Appendix JA4 when thermal mass is used above the roof membrane. This exception is intended to allow ballasted roofs, concrete pavers and other massive elements to be explicitly modeled. To qualify, the weight of the stone ballast, the concrete pavers or other elements must exceed 15 lb/ft<sup>2</sup>. The thickness, heat capacity, conductance and density of the additional mass layer shall be based on the measured physical properties of the material. If the surface properties of the additional mass material have been verified through the Cool Roof Rating Council (CRRC), the CRRC reported properties may be used for the proposed design; otherwise, the mass layer shall be modeled with an aged reflectance of 0.10 and an emittance of 0.85.

#### Assembly Name

<i>Applicability</i>	All projects
<i>Definition</i>	The name of a construction assembly that describes a roof, wall, or floor assembly. The name generally needs to be unique so it can be referenced precisely by surfaces.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	Construction name is a required input. The name should reference the table number, row and column in Reference Appendix JA4.
<i>Standard Design</i>	Not applicable

#### Specification Method

<i>Applicability</i>	All projects
<i>Definition</i>	The method of describing a construction assembly. The more simple method is to describe the U-factor of the construction assembly which can account for thermal bridging and other factors. However with this method, the time delay of heat transfer through the construction assembly is not accounted for. Generally, with the U-factor method, heat transfer is assumed to occur instantly. The more complex method is to describe the construction assembly as a series of layers, each layer representing a material. With this method, heat transfer is delayed in accord with the thermal mass and other properties of the assembly.
<i>Units</i>	List: layers
<i>Input Restrictions</i>	The layers method shall be used for all constructions except for metal building or similar constructions with negligible thermal mass.
<i>Standard Design</i>	For each construction, the proposed design specification method shall be used.

#### Layers

<i>Applicability</i>	All construction assemblies that use the layers method of specification
<i>Definition</i>	A structured list of material names that describe a construction assembly, beginning with the exterior finish and progressing through the assembly to the interior finish. Material names must be from ACM Appendix 5.5A.
<i>Units</i>	List: layers of construction assembly
<i>Input Restrictions</i>	The user is required to describe all layers in the actual assembly and model the proposed design based the layer descriptions.
<i>Standard Design</i>	See building descriptors for Roofs, Exterior Walls, Exterior Floors, Doors, Fenestration and Below Grade Walls.

### 5.5.3 Roofs

#### Roof Name

<i>Applicability</i>	All roof surfaces
<i>Definition</i>	A unique name or code that identifies the roof and ties it to the construction documents submitted for energy code review. It is not mandatory to name roofs.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	None

#### Roof Type

<i>Applicability</i>	All roof surfaces
<i>Definition</i>	<p>A roof classification defined in the Standards. The prescriptive U-factor requirements for roofs depend on the roof type and the climate. For California, the roof classification is determined from the proposed design construction choice from Reference Appendix JA4.</p> <p>This descriptor can be derived from other building descriptors and it may not be necessary for the software user to specify it directly.</p>
<i>Units</i>	List: metal building, wood framed or other
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The roof classification shall be metal building.

#### Roof Geometry

<i>Applicability</i>	All roofs, required input
<i>Definition</i>	Roof geometry defines the position, orientation, azimuth, tilt, and dimensions of the roof surface. The details of how the coordinate system is implemented may vary between software programs. The data structure for surfaces is described in the reference section of this chapter.
<i>Units</i>	Data structure: surface
<i>Input Restrictions</i>	There are no restrictions other than that the surfaces defined must agree with the building being modeled, as represented on the construction drawings or as-built drawings.
<i>Standard Design</i>	<p>Roof geometry will be identical in the proposed and standard design building designs.</p> <p>For alterations, roof geometry will be fixed, based on one of the building prototypes (office, retail, etc.)</p>

#### Roof Construction

<i>Applicability</i>	All roofs, required input
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for roof construction type.
<i>Units</i>	List: layers

**Input Restrictions** The construction assembly, defined by a series of layers, must be equal to or more efficient than the mandatory U-factor requirements of Section 120.7 of the Standards for new construction, and Section 141.0 of the Standards for alterations. Each layer specified must be listed in the materials database in the ACM Appendix 5.5A. Appropriate R-values for insulation can be calculated using the formula below.

$$R_{\text{insulation}} = (1/U\text{-factor}) - R_{\text{layer}(1)} - R_{\text{layer}(2)} - R_{\text{layer}(3)} - R_{\text{layer}(n)}$$

$$R_{\text{insulation}} = R_{\text{ins.continuous}} + R_{\text{ins.framing}}$$

**Standard Design** For new construction, the standard design roof type is metal framed. The U-factor required for roof construction is defined in Table 140.3-B, C or D of the Standards. Programs that model a U-factor shall use an outside air film resistance and an inside air film resistance of R-0.17 and R-0.62, respectively.

For *metal building* roofs, the standard design construction shall include the following layers:

Outside Air Film	R - 0.17
Roof Gravel or Slag (1.0 in.)	R - 0.10
Insulation Entirely Above Deck	$R_{\text{insulation}}$
Plywood (1/2 in.)	R - 0.63
Metal Deck	R - 0.00
Metal Framing	R - 0.00
Air Layer (4 in. or more)	R - 0.92
Acoustic Tile (3/4 in.)	R - 1.89
Inside Air Film	R - 0.62

The R-value of Insulation Entirely Above Deck shall be set to achieve the following U-factors:

#### **Nonresidential Buildings**

Climate Zones 2, 3, 4, 9-16: U=0.039

Climate Zones 1, 5: U=0.049

Climate Zones 7, 8: U=0.067

Climate Zones 6: U=0.075

#### **High-Rise Residential Buildings and Hotel Guestrooms**

Climate Zones 2,4,8-16: U=0.028

Climate Zone 1: U=0.034

Climate Zone 3, 5-7: U=0.039

For alterations, any approved roof type may be used. The U-factor in the standard design shall be modeled as the more efficient of either the existing conditions or the values stated in Section 141.0 of the Standards. Where applicable, selection shall be based on building type, assembly, and climate zone. A construction of layers shall be defined to yield an equivalent U-factor.

For roof construction, the alteration standard design assembly shall include the appropriate existing layers.

### 5.5.4 Exterior Walls

#### Wall Name

<i>Applicability</i>	All walls, optional input
<i>Definition</i>	A unique name or code that relates the exterior wall to the design documents. This is an optional input since there are other acceptable ways to key surfaces to the construction documents.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	None

#### Wall Type

<i>Applicability</i>	All wall surfaces, optional
<i>Definition</i>	<p>One of four categories of above-grade wall assemblies used to determine minimum insulation requirements for walls. The four wall type categories are as follows:</p> <ul style="list-style-type: none"> <li>a) Mass walls,</li> <li>b) Metal building walls,</li> <li>c) Metal framing walls, and</li> <li>c) Wood framing and other walls.</li> </ul> <p>These wall types are defined in Reference Appendix JA4.</p>
<i>Units</i>	List: mass walls, metal building walls, metal framing walls, and wood framing and other walls
<i>Input Restrictions</i>	This input is optional for the purposes covered by this manual. This input can often be derived from other inputs and may not need to be explicitly specified.
<i>Standard Design</i>	All walls in the standard design building are modeled as “metal framed.”

#### Wall Geometry

<i>Applicability</i>	All walls, required input
<i>Definition</i>	Wall geometry defines the position, orientation, azimuth, and tilt of the wall surface. The details of how the coordinate system is implemented may vary between simulation engines. The data structure for surfaces is described in the reference section of this chapter.
<i>Units</i>	Data structure: surface
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Wall geometry in the standard design building is identical to the proposed design.

#### Wall Construction

<i>Applicability</i>	All walls that use the Layers method
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior)

	layer and the last layer represents the inside (or interior) layer. See the building descriptors above for wall construction type.																
<i>Units</i>	List: Layers																
<i>Input Restrictions</i>	<p>The construction assembly, defined by a series of layers, must be equal to or more efficient than the mandatory U-factor requirements of Section 120.7 of the Standards for new construction, and Section 141.0 of the Standards for alterations. Each layer specified must be listed in the materials database in the ACM Appendix 5.5A. Appropriate R-values for insulation can be calculated using the formula below.</p> $R_{\text{insulation}} = (1/U\text{-factor}) - R_{\text{layer}(1)} - R_{\text{layer}(2)} - R_{\text{layer}(3)} - R_{\text{layer}(n)}$ $R_{\text{insulation}} = R_{\text{ins.continuous}} + R_{\text{ins.framing}}$																
<i>Standard Design</i>	<p>For new construction, the standard design wall type is metal-framed with continuous insulation as described in Table 4.3.3 of Reference Appendix JA4. The U-factor required for wall construction of the standard design building is defined in Table 140.3-B, C or D of the Standards. Programs that model a U-factor shall use an outside air film resistance and an inside air film resistance of R-0.17 and R-0.62, respectively.</p> <p>For <i>metal framed</i> walls, the standard design construction shall include the following layers:</p> <table> <tr> <td>Outside Air Film</td><td>R - 0.17</td></tr> <tr> <td>Stucco, 7/8"</td><td>R - 0.18</td></tr> <tr> <td>Building Paper</td><td>R - 0.06</td></tr> <tr> <td>Insulation Continuous</td><td><math>R_{\text{insulation}}</math></td></tr> <tr> <td>Metal Framing, no Insulation</td><td>R - 0.00</td></tr> <tr> <td>Air Layer (4 in. or more)</td><td>R - 0.92</td></tr> <tr> <td>Gypsum board (5/8 in.)</td><td>R - 0.56</td></tr> <tr> <td>Inside Air Film</td><td>R - 0.62</td></tr> </table> <p>For alterations, any approved wall type may be used. The U-factor in the standard design shall be modeled as the more efficient of either the existing conditions or the values stated in Section 141.0 of the Standards. Where applicable, selection shall be based on building type, assembly, and climate zone. A construction of layers shall be defined to yield an equivalent U-factor.</p> <p>For wall construction, the alteration standard design assembly shall include the appropriate existing layers.</p>	Outside Air Film	R - 0.17	Stucco, 7/8"	R - 0.18	Building Paper	R - 0.06	Insulation Continuous	$R_{\text{insulation}}$	Metal Framing, no Insulation	R - 0.00	Air Layer (4 in. or more)	R - 0.92	Gypsum board (5/8 in.)	R - 0.56	Inside Air Film	R - 0.62
Outside Air Film	R - 0.17																
Stucco, 7/8"	R - 0.18																
Building Paper	R - 0.06																
Insulation Continuous	$R_{\text{insulation}}$																
Metal Framing, no Insulation	R - 0.00																
Air Layer (4 in. or more)	R - 0.92																
Gypsum board (5/8 in.)	R - 0.56																
Inside Air Film	R - 0.62																

### 5.5.5 Exterior Floors

Floor Name	
<i>Applicability</i>	All floor surfaces
<i>Definition</i>	<p>A unique name or code that relates the exposed floor to the design documents. Exposed floors include floors exposed to the outdoors and floors over unconditioned spaces, but do not include slab-on-grade floors, below grade floors, or interior floors.</p>
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None

*Standard Design* None

### **Floor Type**

*Applicability* All exterior floor surfaces, optional

*Definition* One of three categories of exposed floor assemblies used to determine minimum prescriptive insulation requirements. The three floor type categories are:

- a) Mass floor,
- b) Steel framed floor, and
- c) Wood framed and other floors.

Explanations of these three exterior floor types are contained in Reference Appendix JA4. This building descriptor is not used for the purposes of this manual, since the type for the standard design building is fixed at “steel joist”. This building descriptor can often be derived from other information in the model and may not be required as an explicit input.

*Units* List: mass floor, metal joist floor, and wood and other floors

*Input Restrictions* This building descriptor input is optional for the purposes of this manual.

*Standard Design* The standard design building floors shall be of type “steel joist.”

### **Floor Geometry**

*Applicability* All exterior floors, required input

*Definition* Floor geometry defines the position, orientation, azimuth, and tilt of the floor surface. The details of how the coordinate system is implemented may vary between software programs. The data structure for surfaces is described in the reference section of this chapter.

*Units* Data structure: surface

*Input Restrictions* As designed

*Standard Design* Standard design building floor geometry is identical to the proposed design.

### **Floor Construction**

*Applicability* All floors, required input

*Definition* A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for floor construction type.

*Units* List: Layers

*Input Restrictions* The construction assembly, defined by a series of layers, must be equal to or more efficient than the mandatory U-factor requirements of Section 120.7 of the Standards for new construction, and Section 141.0 of the Standards for alterations. Each layer specified must be listed in the materials database in the ACM Appendix 5.5A. Appropriate R-values for insulation can be calculated using the formula below.

$$R_{\text{insulation}} = (1/U\text{-factor}) - R_{\text{layer}(1)} - R_{\text{layer}(2)} - R_{\text{layer}(3)} - R_{\text{layer}(n)}$$

$$R_{\text{insulation}} = R_{\text{ins.continuous}} + R_{\text{ins.framing}}$$

*Standard Design* For new construction, the floor type for the standard design building is steel framed.

The U-factor required for floor construction is defined in Table 140.3-B, C or D of the Standards. Programs that model a U-factor shall use an outside air film resistance and an inside air film resistance of R-0.17 and R-0.62, respectively.

For *steel framed* floors, the standard design construction shall include the following layers:

Outside Air Film	R - 0.17
Exterior Finish (metal or none)	R - 0.00
Insulation / Continuous	R <sub>insulation</sub>
Steel joists	R – 0.00
Air Layer (4 in. or more)	R - 0.92
Wood sheathing (5/8 in.)	R - 0.78
Carpet with Fibrous Pad	R - 2.08
Inside Air Film (down)	R - 0.92

For alterations, any approved floor type may be used. The U-factor in the standard design shall be modeled as the more efficient of either the existing conditions or the values stated in Section 141.0 of the Standards. Where applicable, selection shall be based on building type, assembly, and climate zone. A construction of layers shall be defined to yield an equivalent U-factor.

For floor construction, the alteration standard design assembly shall include the appropriate existing layers.

## 5.5.6 Doors

### Door Name

<i>Applicability</i>	All exterior doors, optional input
<i>Definition</i>	A unique name or code that relates the door to the design documents submitted. Doors that are more than 50% glass are treated as windows and must be determined and entered by using the <i>Fenestration</i> building descriptors.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	None

### Door Type

<i>Applicability</i>	All exterior doors, required input
<i>Definition</i>	One of two door classifications of either: swinging or non-swinging. Non-swinging are generally roll-up doors. The prescriptive U-factor requirements depend on door type and climate. This building descriptor may be derived from other building descriptors, in which case a specific input is not necessary.
<i>Units</i>	List: swinging or non-swinging
<i>Input Restrictions</i>	The door type shall be consistent with the type of door represented on the construction

documents or as-built drawings.

*Standard Design* The standard design building door type shall be the same as the proposed design.

### **Door Geometry**

*Applicability* All exterior doors

*Definition* Door geometry defines the position and dimensions of the door surface relative to its parent wall surface. The azimuth and tilt (if any) of the door is inherited from the parent surface. The position of the door within the parent surface is specified through X,Y coordinates. The size is specified as a height and width (all doors are generally assumed to be rectangular in shape). The details of how the geometry of doors is specified may vary for each energy simulation program.

*Units* Data structure: opening

*Input Restrictions* As designed

*Standard Design* Door geometry in the standard design building is identical to the proposed design.

### **Door Construction**

*Applicability* All exterior doors

*Definition* The thermal transmittance of the door, including the frame.

*Units* Btu/h·ft<sup>2</sup>·°F

*Input Restrictions* The construction assembly must be equal to or more efficient than the mandatory U-factor requirements of Section 110.6 of the Standards for new construction. For alterations there are no restrictions.

*Standard Design* For new construction, the U-factor required for door construction is defined in Table 140.3-B, C or D of the Standards.

For alterations, the U-factor in the standard design shall be modeled as the more efficient of either the existing conditions or the values stated in Table 140.3-B, C or D of the Standards. Where applicable, selection shall be based on building type, assembly, and climate zone.

## **5.5.7 Fenestration**

Note that fenestration includes windows, doors that have more than 50% glazed area, and skylights. A skylight is fenestration that has a tilt of less than 60° from horizontal.

### **Fenestration Name**

*Applicability* All fenestration, optional input

*Definition* A unique name or code that relates the fenestration to the design documents and a parent surface.

*Units* Text: unique

*Input Restrictions* No restrictions

*Standard Design* Not applicable

### **Fenestration Type (Vertical Fenestration)**

*Applicability*

	All vertical fenestration
<i>Definition</i>	This is a classification of vertical fenestration that determines the thermal performance and solar performance requirement for vertical fenestration.
<i>Units:</i>	List: Fixed, Operable, Curtain Wall, or Glazed Doors
<i>Input Restrictions</i>	No restrictions, other than that the vertical fenestration type must agree with the type specified on the construction documents or the as-built drawings.
<i>Standard Design</i>	Same as the proposed design

#### **Fenestration Type (Skylights)**

<i>Applicability</i>	All skylights
<i>Definition</i>	This is a classification of skylights that determines the thermal performance and solar performance requirement for vertical fenestration.
<i>Units:</i>	List: Glass, curb-mounted, Glass, deck-mounted, or Plastic
<i>Input Restrictions</i>	No restrictions, other than the skylight types specified must agree with the construction documents or the as-built drawings.
<i>Standard Design</i>	Same as the proposed design

#### **Default Fenestration Type**

<i>Applicability</i>	All fenestration that uses default thermal performance factors
<i>Definition</i>	This is a classification of fenestration that determines the thermal performance for fenestration using defaults from Standards Section 110.6
<i>Units:</i>	List: Fixed, Operable, Greenhouse/garden, doors, or Skylight
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### **Default Glazing Type**

<i>Applicability</i>	All fenestration that uses default thermal performance factors
<i>Definition</i>	This is a classification of fenestration that determines the thermal performance for fenestration using defaults from Standards Section 110.6
<i>Units:</i>	List: Single Pane, Double Pane, Glass Block
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### **Fenestration Geometry**

<i>Applicability</i>	All fenestration
<i>Definition</i>	<p>Fenestration geometry defines the position and dimensions of the fenestration surface within its parent surface and the identification of the parent surface. The orientation and tilt is inherited from the parent surface. The details of how the coordinate system is implemented may vary between Compliance Software programs.</p> <p>Display Perimeter. Display perimeter is the length of an exterior wall in a B-2 occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk. The compliance software shall allow the</p>

user to specify a value for the length of display perimeter, in feet, for each floor or story of the building. The user entry for Display Perimeter shall have a default value of zero. Note: Any non-zero input for Display Perimeter is an exceptional condition that shall be reported on the PERF-1 exceptional condition list and shall be reported on the ENV forms. The value for Display Perimeter is used as an alternate means of establishing Maximum Wall Fenestration Area in the standard design (§140.3 of the Standards).

Floor Number. The compliance software shall also allow the user to specify the Display Perimeter associated with each floor (story) of the building.

**Units**

Data structure: opening

Geometry is defined relative to the parent surface and can include setbacks.

Inputs include:

Geometry of opening (window or skylight), parent surface, display perimeter (optional), percent of roof area exempt from skylight requirements §140.3 of the Standards.

**Input Restrictions**

As designed.

Specification of the fenestration position within its parent surface is required for the following conditions:

- 1) Exterior shading is modeled from buildings, vegetation, other objects; or
- 2) If daylighting is modeled within the adjacent space.

**Standard Design**

The standard design calculates the window wall ratio (WWR) for each orientation and the overall window wall ratio for the building. The window wall ratio is the total fenestration area (including framing) divided by the gross exterior wall area.

The geometry of the fenestration in the standard design shall be identical to the proposed design with the following exceptions:

*Exception 1.* Either the whole building window wall ratio or west window wall ratio exceeds 40%.

*Exception 2.* If display perimeter is entered, the fenestration area exceeds six times the display perimeter.

**Exception 1.** The fenestration is adjusted based on the following conditions:

Case 1.  $WWR_o > 0.40$ ,  $WWR_w \leq 0.40$

In this case, the fenestration area of all windows is reduced by multiplying the fenestration area by the ratio  $0.40/WWR_o$ . The dimensions of each window is reduced by multiplying the proposed window dimension by  $(0.40/WWR_o)^{1/2}$ , so that the same window aspect ratio is maintained.

Case 2:  $WWR_o < 0.40$ .  $WWR_w > 0.40$

In this case, the fenestration area of all windows on the west orientation is reduced by multiplying the fenestration area by the ratio  $0.40/WWR_o$ . The dimensions of each window is reduced by multiplying the proposed window dimension by  $(0.40/WWR_o)^{1/2}$ , so that the same window aspect ratio is maintained.

Case 3:  $WWR_o > 0.40$ .  $WWR_w > 0.40$

If both the west window wall ratio and the overall window wall ratio exceed the prescriptive limit of 0.40, the fenestration areas must be reduced by:

- 1) Adjust the West window area multiplying the west window area by the ratio  $0.4/WWR_w$ .

- 2) Calculate the WWR of the north, east and south facades:

$$WWR_{nes} = \text{Window Area}_{nes} / \text{Gross Wall Area}_{nes}$$

- 3) Adjust the window area of the windows on the north, east and south facades by the following ratio:

$$\text{WindowArea}_{N,std} = \text{WindowArea}_{N,prop} \times 0.4 / WWR_{nes}$$

$$\text{WindowArea}_{E,std} = \text{WindowArea}_{E,prop} \times 0.4 / WWR_{nes}$$

$$\text{WindowArea}_{S,std} = \text{WindowArea}_{S,prop} \times 0.4 / WWR_{nes}$$

- 4) Adjust each window geometry for the west façade by multiplying each dimension by  $(0.4/WWR_w)^{1/2}$
- 5) Adjust each window geometry for the north, east and south façade by multiplying each dimension by  $(0.4/WWR_{nes})^{1/2}$

**Exception 2.** If the display perimeter is entered and the window area exceeds the prescriptive limit, the window area for the standard design is calculated by multiplying the proposed window area by the following ratio:

$$\text{WindowArea}_{std} = 6 \times \text{DisplayPerimeter}$$

The geometry of each window is modified by the following:

$$\text{WindowHeight}_{std} = \text{WindowHeight}_{prop} \times (\text{WindowArea}_{std} / \text{WindowArea}_{prop})^{1/2}$$

$$\text{WindowWidth}_{std} = \text{WindowWidth}_{prop} \times (\text{WindowArea}_{std} / \text{WindowArea}_{prop})^{1/2}$$

The following rules apply for calculating geometry of skylights:

The ratio of the total skylight area of the building to the total roof area, also called the Skylight to Roof ratio (SRR)  $\leq 0.05$ , except for Atrium spaces with a ceiling height over 55 feet where  $SRR \leq 0.10$ .

Depending on the following condition, adjustments to the SRR as described below shall be made.

- i. For spaces other than auditoriums, churches, movie theaters, museums and refrigerated warehouses- Building Floor area  $\times 0.75 =$  Total primary daylight area+ Total skylit daylight area. See 5.4.4 for detail description on Primary Daylit area and Skylit Daylit area.
- ii. If the above condition is met and  $SRR \leq 0.05$ , no adjustments are needed.
- iii. If the condition is met and  $SRR > 0.05$ , skylight dimensions = Existing Dimension  $\times [1 - \sqrt{(0.05/SRR \text{ of Proposed Building})}]$
- iv. If the condition is not met triggering the need for additional skylights, the baseline case shall be modeled with new skylights irrespective of the skylight location of the proposed case. The new skylights shall be distributed uniformly such that there is no overlapping of primary daylight areas from skylights or sidelights. The dimension of the new skylights shall be the same as the proposed design if calculated new  $SRR \leq 0.05$ . If  $SRR > 0.05$ , skylight dimensions = Existing Dimension  $\times [1 - \sqrt{(0.05/SRR \text{ of Proposed Building})}]$ .

Note that the adjustments to SRR is done after adjustments to WWR, if any is completed.

#### Skylight Requirement Exception Fraction

Applicability	All buildings with interior ceiling heights greater than 15 feet
Definition	This is the fraction of floor area that is exempt from the minimum skylight area

requirement for spaces with high ceilings.

### Identifying areas subject to §140.3 of the Standards

When a proposed space has ceiling heights greater than 15 feet, with exterior surfaces having a tilt angle less than 60 degrees (roofs) and no more than 3 stories above grade, the user shall enter the fraction of the modeled space that is exempt from requirements of §140.3 of the Standards. If the proposed design has skylights, the user shall also indicate the area of the proposed design daylight area under skylights in this space. When the user enters a value greater than 0 % for the fraction of the space area exempt to §140.3 of the Standards, the compliance software shall require that the user indicate at least one of the following exceptions:

1. Designed general lighting is less than 0.5 W/ft<sup>2</sup>
2. Existing walls on plans result in enclosed spaces less than 5,000 ft<sup>2</sup>
3. Future walls or ceilings on plans result in enclosed spaces less than 5,000 ft<sup>2</sup> or ceiling heights less than 15 feet.
4. Plans or documents show that space is an auditorium, religious building of worship, movie theater, museum, or refrigerated warehouses.

<i>Units:</i>	Data Structure: (a) Unitless fraction between 0 and 1 List: Four exceptions listed above (specified if fraction > 0)
<i>Input Restrictions</i>	No restrictions, other than that the vertical fenestration type must agree with the type specified on the construction documents or the as-built drawings.
<i>Standard Design</i>	Same as the proposed design

### Fenestration Construction

<i>Applicability</i>	All fenestration
<i>Definition</i>	A collection of values that together describe the performance of a fenestration system. The values that are used to specify the criteria are U-factor, SHGC and VT. U-factor and SHGC inputs are whole-window values.
<i>Units</i>	Data structure: shall include at a minimum the following properties as specified by NFRC ratings:  U-factor: whole window U-factor  SHGC: whole window solar heat gain coefficient  VT: visible transmittance
<i>Input Restrictions</i>	For new construction, performance information for fenestration shall be developed from NFRC test procedures or shall be equal to or more efficient than the requirements of Section 110.6 of the Standards, and the default values in Tables 110.6-A and B of the Standards. Center-of-glass performance values for windows complying with the exception (maximum of 1,000 ft <sup>2</sup> ) Values entered shall be consistent with the specifications and the construction documents.  For buildings with fenestration area that meets requirements for use of center-of-glass U-factor and SHGC, the window overall U-factor, SHGC and VT shall be determined by the following equations from the Reference Appendix NA6:

$$U_T = C_1 + (C_2 \cdot U_c)$$

$$SHGC_T = 0.08 + (0.86 \cdot SHGC_c)$$

$$VT_T = VT_F \cdot VT_C$$

Where,

$U_T$  = U-factor Is the Total Performance of the fenestration including glass and frame

$C_1$  = Coefficient selected from Table NA6-5 in Reference Appendix NA6

$C_2$  = Coefficient selected from Table NA6-5 in Reference Appendix NA6

$U_c$  = Center of glass U-factor calculated in accordance with NFRC 100 Section 4.5.3.1

$SHGC_T$  = SHGC Is

$SHGC_c$  = Center of glass SHGC calculated in accordance with NFRC 200 Section 4.5.1.1

$VT_T$  = Is the Total Performance of the fenestration including glass and frame

$VT_F = 0.53$  for projecting windows, such as casement and awning windows

$VT_F = 0.67$  for operable or sliding windows

$VT_F = 0.77$  for fixed or non-operable windows

$VT_F = 0.88$  for curtain wall/storefront, Site-built and manufactured non-curb mounted skylights

$VT_F = 1.0$  for Curb Mounted manufactured Skylights

$VT_C$  = Center of glass VT is calculated in accordance with NFRC 200 Section 4.5.1.1 or NFRC 202 for Translucent Products or NFRC 203 for Tubular Daylighting Devices and Hybrid Tubular Daylighting Devices or ASTM E972

For skylights, the default values shall be the alternate default U-factor and SHGC using default calculations specified above and in Reference Appendix NA6 or the U-factor and SHGC listed in Table 110.6-A and Table 110.6-B in the Standards.

For alterations, the U-factor, SHGC and VT must be equal to or more efficient than the mandatory requirements of Section 141.0 of the Standards.

**Standard Design** For new construction, the requirements for vertical fenestration U factor, Solar Heat Gain Coefficient, and Visible light transmission by window type and framing type are specified in Table 140.3-B, C or D of the Standards.

For alterations, the U-factor, SHGC and VT in the standard design shall be modeled as the more efficient of either the existing conditions, or the values stated in Table 141.0-A of the Standards when the existing window area is unchanged, or Table 140.3-B, C or D of the Standards for all other cases.

### External Shading Devices

**Applicability** All fenestration

**Definition** Devices or building features that are documented in the construction documents and shade the glazing, such as overhangs, fins, shading screens, and setbacks of windows from the exterior face of the wall. Objects that shade the building but are not

part of the building and parts of the building that cause the building to shade itself are also modeled, but are not a part of this building descriptor. See *Shading of the Building Site*. The Title 24 compliance software shall be capable of modeling vertical fins and overhangs. Recessed windows may also be modeled with side fins and overhangs.

<i>Units</i>	Data structure: opening shade
<i>Input Restrictions</i>	No restrictions other than that the inputs must match the construction documents
<i>Standard Design</i>	The standard design building is modeled without external shading devices.

#### **Internal Shading Devices**

<i>Applicability</i>	All fenestration
<i>Definition</i>	Curtains, blinds, louvers, or other devices that are applied on the room side of the glazing material. Glazing systems that use blinds between the glazing layers are also considered internal shading devices. Glass coatings, components or treatments of the glazing materials are addressed through the <i>Fenestration Construction</i> building descriptor.
<i>Units</i>	Data structure: Indicates the type of control, or blind schedule if applicable
<i>Input Restrictions</i>	Interior shades shall only be modeled when automatic controls are present.
<i>Standard Design</i>	The standard design building shall be modeled with the same internal shading devices and shading schedule as the proposed design.

#### **SHGC Dim Fraction**

<i>Applicability</i>	Fenestration with switchable glazing
<i>Definition</i>	For switchable glazing, this is the fraction of the solar heat gain coefficient when darkened to the solar heat gain coefficient during normal operation. This can be applied when the solar heat gain exceeds a specified threshold, or controlled by an electrical signal.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	Between 0 and 1
<i>Standard Design</i>	Not applicable

#### **VT Dim Fraction**

<i>Applicability</i>	Fenestration with switchable glazing
<i>Definition</i>	For switchable glazing, this is the fraction of the visible transmittance when darkened to the visible transmittance during normal operation. This can be applied when the solar heat gain exceeds a specified threshold, or controlled by an electrical signal.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	Between 0 and 1
<i>Standard Design</i>	Not applicable

#### **Switchable Solar Heat Gain Threshold**

<i>Applicability</i>	Fenestration with automatically controlled switchable glazing.
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<i>Definition</i>	For switchable glazing, this is the solar heat gain threshold above which the dynamic glazing is active (darkened). When the solar heat gain drops below this threshold, the glazing is switched back to being inactive (clearest setting). Indoor and outdoor air temperatures are the setpoints required for controlling the Switchable Solar Heat Gain Threshold. A flag may be used to indicate that this control is not used.
<i>Units</i>	Incident solar threshold (Btu/h-ft <sup>2</sup> )
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Not applicable

#### **Switchable Space Temperature Threshold**

<i>Applicability</i>	Fenestration with automatically controlled switchable glazing.
<i>Definition</i>	For switchable glazing, this is the space temperature above which the dynamic glazing is active (darkened). When the solar heat gain drops below this threshold, the glazing is switched back to being inactive (clearest setting). Indoor and outdoor air temperatures are the setpoints required for controlling the Switchable Solar Heat Gain Threshold. This may be used in combination with the solar heat gain and illuminance thresholds for control. A flag may be used to indicate that this control is not used.
<i>Units</i>	°F
<i>Input Restrictions</i>	The space heating and cooling setpoints are prescribed from Appendix 5.4B. A flag may be used to indicate that this control is not used.
<i>Standard Design</i>	Not applicable

#### **Switchable Illuminance Threshold**

<i>Applicability</i>	Fenestration with automatically controlled switchable glazing.
<i>Definition</i>	For switchable glazing, this is the illuminance threshold above which the dynamic glazing is regulated between active (darkened) and inactive (clearest setting). With a single illuminance setpoint the switchable glazing will adjust between the clearest and darkest setting to allow the desired illuminance level. A flag may be used to indicate that this control is not used.
<i>Units</i>	Lux
<i>Input Restrictions</i>	As designed  During occupied hours, the recommendation for the illuminance threshold setpoint is to match a point within the recommended illumination levels, based on space type, from Appendix 5.4A. Values below this recommended range may require special documentation.  During unoccupied hours, the recommendation is to have the Switchable Solar Heat Gain Threshold descriptor in control of the switchable glass.
<i>Standard Design</i>	Not Applicable

**Switchable Glazing Schedule**

<i>Applicability</i>	Fenestration with switchable glazing controlled by an electrical signal
<i>Definition</i>	For switchable glazing, this is an hourly schedule for the when the switchable glazing is darkened, when controlled by an electrical signal.
<i>Units</i>	Boolean: 1 if switchable glazing is active (darkened); 0 if not active
<i>Input Restrictions</i>	0 or 1 for schedule values
<i>Standard Design</i>	Not applicable

**5.5.8 Below Grade Walls****Below Grade Wall Name**

<i>Applicability</i>	All projects, optional input
<i>Definition</i>	A unique name that keys the below grade wall to the construction documents
<i>Units:</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Not applicable

**Below Grade Wall Geometry**

<i>Applicability</i>	All projects
<i>Definition</i>	A geometric construct that describes the dimensions and placement of walls located below grade. Below grade walls have soil or crushed rock on one side and interior space on the other side. Some simulation models take the depth below grade into account when estimating heat transfer, so the geometry may include height and width.
<i>Units</i>	Data structure: below grade wall geometry
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The geometry of below grade walls in the standard design building is identical to the below grade walls in the proposed design.

**Below Grade Wall Construction**

<i>Applicability</i>	All projects, required input
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for below grade wall construction type.
<i>Units</i>	Data structure: construction assembly  The construction can be described as a C-factor which is similar to a U-factor, except that the outside air film is excluded, or the construction can be represented as a series of layers, like exterior constructions.
<i>Input Restrictions</i>	For new construction, there are no restrictions other than that the inputs shall be in agreement with the construction documents. Values for the C-factor shall be taken from Table 4.3.5, 4.3.6 or 4.3.7 of Reference Appendix JA4.

For alterations there are no restrictions.

*Standard Design* For new construction, See Table 12. The standard design building shall use default values for C-factor. The height shall be the same as specified in the proposed design.

For *below grade* walls, the standard design construction shall include the following layers:

Insulation Continuous	$R_{\text{insulation}}$
Mass Wall	R – (see ACM Appendix 5.5A)
Air Layer (3/4 in. or less)	R - 0.90
Gypsum board (5/8 in.)	R - 0.56
Inside Air Film	R - 0.62

Table 12 – Standard Design Building Below-Grade Wall Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb F)	R-value (ft <sup>2</sup> ·°F·h/Btu)	C-factor (Btu/ft <sup>2</sup> ·°F·h)
NR	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	1.140
R-7.5 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	1.8	0.02	1.8	0.29	7.50	
	Total assembly					8.37	0.119
R-10 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	2.4	0.02	1.8	0.29	10.00	
	Total assembly					10.87	0.092
R-12.5 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	3.0	0.02	1.8	0.29	12.50	
	Total assembly					13.37	0.075

For alterations, the C-factor in the standard design shall be modeled as the more efficient of either the existing conditions, or the values stated above for new construction standard design.

For *below grade* walls, the alteration standard design assembly shall include the appropriate existing layers.

A formula for calculating acceptable monthly ground temperature (below grade exterior surface temperature) is shown below: (source: Energy Plus 7.0)

$$T_{\text{ext.surf}} = T_{\text{ave.space}} - 3.6^{\circ}\text{F}$$

Where:

$T_{\text{ext.surf}}$  = Temperature of below grade exterior surfaces for each month (°F)

$T_{\text{ave.space}}$  = Average monthly dry-bulb temperature of the conditioned below grade space (°F)

Compliance software may use alternate methods of modeling heat transfer between the below-grade walls and the surrounding soil.

### 5.5.9 Slab Floors in Contact with Ground

These building descriptors apply to slab-on-grade floors that are in direct contact with the ground.

**Slab Floor Name**

<i>Applicability</i>	All slab floors, optional
<i>Definition</i>	A unique name or code that relates the exposed floor to the construction documents.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Standard Design</i>	Not applicable

**Slab Floor Type**

<i>Applicability</i>	All slab floors, required
<i>Definition</i>	<p>One of two classes for floors in contact with ground. The classes are:</p> <ol style="list-style-type: none"> <li>1) Heated slab-on-grade floors and,</li> <li>2) Unheated slab-on-grade floors.</li> </ol> <p>Heated slab-on-grade floors include all floors that are heated directly in order to provide heating to the space. Unheated slab-on-grade floors are all other floors in contact with ground.</p>
<i>Units</i>	List: heated or unheated
<i>Input Restrictions</i>	None
<i>Standard Design</i>	The slab floor type in the standard design building is identical to the slab floor type in the proposed design.

**Slab Floor Geometry**

<i>Applicability</i>	All slab floors, required
<i>Definition</i>	<p>A geometric construct representing a slab floor in contact with the earth. The geometric representation can vary depending on how the energy simulation software models slabs-on-grade. Some models require that only the perimeter of the slab be entered. Other models divide the slab into a perimeter band within 2 ft of the edge and the interior portion or core area, such that the perimeter area and the core area sum to the total area of the slab.</p>
<i>Units:</i>	<p>Data structure: as appropriate for the simulation tool</p> <p>This may include: Area, Perimeter Exposed</p>
<i>Input Restrictions</i>	No restrictions
<i>Standard Design</i>	The geometry of the slab floor in the standard design building is identical to the slab floor in the proposed design.

**Slab Floor Construction**

<i>Applicability</i>	All slab floors, required input
<i>Definition</i>	<p>A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for slab floor construction type.</p> <p>A description of how the slab is insulated (or not). How the construction is described will depend on the energy simulation model. The construction can be represented by an F-factor that represents the entire construction (floor and insulation).</p>

Simple models may include just an F-factor, representing an instantaneous heat loss/gain to outside air. The F-factor could be related to the configuration of insulation in the proposed design. Other slab loss models may require that the surface area of the slab floor be divided between the perimeter and the interior. The insulation conditions then define heat transfer between both outside air and ground temperature.

The insulation condition for slabs includes the R-value of the insulation and the distance it extends into the earth at the slab edge and how far it extends underneath the slab.

**Units**

List

**F-factor from Reference Appendix JA4;** this is one selection from list 1 and one selection from list 2. Note that some combinations from list 1 and list3 are not allowed – see Reference Appendix JA4 Table 4.4.8 and Table 4.4.7 for details.

List 1: None, 12 in horizontal, 24 in horizontal, 36 in horizontal, 48 in horizontal, 12 in vertical, 24 in vertical, 36 in vertical, 48 in vertical, Fully insulated slab

List 2: R-0, R-5, R-7.5, R-10, R-15, R-20, R-25, R-30, R-35, R-40, R-45, R-50, R-55

**Input Restrictions**

For new construction, F-factors shall be taken from Table 4.4.8 of Reference Appendix JA4 for heated slab floors and Table 4.4.7 for unheated slab floors. For all methods, inputs shall be consistent with the construction documents. For heated slab floors, the F-factor shall be determined by the mandatory R-value and installation requirements in Section 110.8 of the Standards, and then that information is used in Table 4.4.8 of Reference Appendix JA4 to determine the required F-factor. For alterations the same requirements apply.

**Standard Design**

Slab loss shall be modeled with the simple method (F-factor).

For new construction, the configuration of insulation and the F-factors for the standard design building heated slab floors are shown in Table 4.4.8 in Reference Appendix JA4. The F-factor for the standard design shall be the following:

Climate Zones 1-15: 48 in vertical, R-5 insulation

Climate Zone 16: 48 in vertical, R-10 insulation

For unheated slab floors the standard design Slab Floor Construction shall be *None*.

For alterations, the F-factor in the standard design shall be modeled as the more efficient of either the existing conditions, or the values stated above for new construction standard design.

## 5.5.10 Heat Transfer between Thermal zones

### Partition Name

<b>Applicability</b>	All partitions, optional
<b>Definition</b>	A unique name or code that relates the partition to the construction documents.
<b>Units</b>	Text: unique
<b>Input Restrictions</b>	The text should provide a key to the construction documents.
<b>Standard Design</b>	Not applicable

### Partition Geometry

<b>Applicability</b>	All partitions
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<i>Definition</i>	A geometric construct that defines the position and size of partitions that separate one thermal zone from another. The construct shall identify the thermal zones on each side of the partition. Since solar gains are not generally significant for interior partitions, the geometry of partitions is sometimes specified as just an area along with identification of the thermal zones on each side.
<i>Units</i>	Data structure: surface with additional information identifying the two thermal zones that the partition separates.
<i>Input Restrictions</i>	No restrictions other than agreement with the construction documents
<i>Standard Design</i>	The geometry of partitions in the standard design building shall be identical to the proposed design.

#### **Partition Construction**

<i>Applicability</i>	All partitions
<i>Definition</i>	A description of the construction assembly for the partition
<i>Units</i>	Data structure: construction assembly
<i>Input Restrictions</i>	No restrictions other than the need for agreement with the construction documents
<i>Standard Design</i>	Partitions in the standard design building shall be steel framed walls with 5/8 in. gypsum board on each side.

## **5.6 HVAC Zone Level Systems**

This group of building descriptors relate to HVAC systems at the zone level. There is not a one-to-one relationship between HVAC components in the proposed design and the Standard Design since the Standard Design system is determined from building type, size, and heating source. The eight Standard Design systems are shown as columns in . The building descriptors for zone level HVAC systems are shown as rows and the check marks “✓” indicate that the building descriptor applies for the Standard Design system. Depending on the nature of the proposed design, any of the building descriptors could apply. Additions and Alterations should follow the same requirements stated for new construction Proposed Designs and new construction Standard Designs; unless otherwise noted in the descriptor.

### **5.6.1 Space Temperature Control**

#### **Control System Type**

<i>Applicability</i>	All buildings
<i>Definition</i>	<p>The type of control system for the building. This input affects baseline system specification for zone level controls, supply air temperature reset controls, ventilation controls and fan and pump static pressure part-load curves. See the following building descriptors:</p> <p>Ventilation Control Method</p> <p>Terminal Heating Control Type</p> <p>Pump Part-Load Curve</p>

	Fan Part-load Curve
<i>Units</i>	None
<i>Input Restrictions</i>	List: can be one of the following inputs  DDC Control to the Zone Level – direct digital control systems with control to the zone level  Other – other control systems, including pneumatic and DDC systems without control to the zone level
<i>Standard Design</i>	DDC Control to the Zone Level

#### **Space Thermostat Throttling Range**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The number of degrees that the room temperature must change to cause the HVAC system to go from no heating or cooling (i.e., space temperatures floating) to full heating or cooling.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	The prescribed value is 2°F. No input is needed and the prescribed value may not be overridden.
<i>Standard Design</i>	Same as the proposed design

#### **Space Temperature Schedule**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	An hourly space thermostat schedule
<i>Units</i>	Data structure: temperature schedule
<i>Input Restrictions</i>	The schedules specified in Appendix 5.4A and detailed in Appendix 5.4B shall be used as a default. When the default temperature schedule is overridden, the user must provide justification for use of nonstandard space temperature schedule assumptions.
<i>Standard Design</i>	Schedules in the Standard Design shall be identical to the proposed design.

## **5.6.2 Terminal Device Data**

#### **Terminal Type**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	A terminal unit includes any device serving a zone (or group of zones collected in a thermal zone) that has the ability to reheat or recool in response to the zone thermostat. This includes: <ul style="list-style-type: none"> <li>• None (the case for single zone units)</li> <li>• VAV box</li> <li>• Series Fan-Powered VAV box</li> <li>• Parallel Fan-Powered VAV box</li> <li>• Induction-type VAV box</li> </ul>

- Dual-duct mixing box (constant volume and VAV)
- Two and three duct mixing dampers (multi-zone systems)
- Reheat coil (constant volume systems)
- Perimeter induction units

*Units* List (see above)

*Input Restrictions* As designed

*Standard Design* Table 13 specifies the HVAC terminal device for each of the Standard Design systems. See Table 5 – HVAC System Map for a summary of the HVAC mapping.

**Table 13 – Standard Design HVAC Terminal Devices**

Standard Design System	Terminal Type
System 1 – PTAC	None
System 2 – FPFC	None
System 3 – PSZ-AC	None
System 5 – Packaged VAV with Reheat	VAV Box
System 6 – VAV with Reheat	VAV Box
System 7 – SZVAV	None
System 9 – Heating and Ventilation	None
System 10 – CRAH	None
System 11 – CRAC	None

### 5.6.3 Terminal Heating

This group of building descriptors applies to proposed design systems that have reheat coils at the zone level. The building descriptors are applicable for Standard Design systems 5 and 6.

#### **Terminal Heat Type**

*Applicability* Systems that have reheat coils at the zone level

*Definition* The heating source for the terminal unit. This includes:

- Electric resistance
- Gas furnace
- Oil furnace
- Hot water
- Steam

*Units* List (see above)

*Input Restrictions* As designed.

*Standard Design* Table 14 shows the terminal heat type for each Standard Design system.

Table 14 – Baseline Building Terminal Heat Type

Baseline building System	Terminal Heat Type
System 1 – PTAC	None
System 2 – PTHP	None
System 3 – PSZ-AC	None
System 4 – PSZ-HP	None
System 5 – Packaged VAV with Reheat	Hot Water
System 6 – VAV with Reheat	Hot Water
System 7 – SZVAV	None
System 8 – SZVAV HP	None
System 9 – Heating and Ventilation	None
System 10 – CRAH Unit	None
System 11 – CRAC Unit	None

**Terminal Heat Capacity**

<i>Applicability</i>	Systems that have reheat coils at the zone level
<i>Definition</i>	The heating capacity of the terminal heating source
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed. However, if the unmet load hours exceed 300, the energy analyst and design team may have to increase the size of the equipment so that the unmet load hours are less than 300. See Figure 7.
<i>Standard Design</i>	The software shall automatically size the terminal heating capacity to be 25% greater than the design loads. See Figure 7.

**Reheat Delta T**

<i>Applicability</i>	Systems that have reheat coils at the zone level
<i>Definition</i>	This is an alternate method to enter the terminal heat capacity. It can be calculated as follows:

(3)

$$\Delta T_{\text{reheat}} = T_{\text{reheat}} - T_{\text{cool\_supply}}$$

$$\Delta T_{\text{reheat}} = Q_{\text{coil}} / (1.1 \cdot \text{CFM})$$

where

$\Delta T_{\text{reheat}}$  heat rise across the terminal unit heating coil (°F)

$T_{\text{reheat}}$  heating air temperature at design (°F)

$T_{\text{cool\_supply}}$  supply air temperature at the heating coil (°F)

$Q_{\text{coil}}$  heating coil load (Btu/h)

CFM airflow (cfm)

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed, but may need to be increased if unmet load hours are greater than 300.

*Standard Design* Method not used for standard design. (The temperature difference shall be no more

than 40F.) See Heat Capacity above.

## 5.6.4 Baseboard Heat

### Baseboard Capacity

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The total heating capacity of the baseboard unit(s)
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable to the standard design

### Baseboard Heat Control

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	Defines the control scheme of base board heating as either: <ul style="list-style-type: none"> <li>Controlled by a space thermostat</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	Controlled by space thermostat is the only type allowed if baseboard heating is used.
<i>Standard Design</i>	Not applicable for the standard design

## 5.6.5 Zone Level Air Flow

### 5.6.5.1 VAV Air Flow

This group of building descriptors applies to proposed design systems that vary the volume of air at the zone level. The building descriptors are applicable for standard design systems 5 and 6.

### Design Airflow

<i>Applicability</i>	Systems that vary the volume of air at the zone level
<i>Definition</i>	The air delivery rate at design conditions
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed. If the unmet load hours in the proposed design are greater than 300, the building descriptor may need to be modified to meet the criterion.
<i>Standard Design</i>	For systems 5 and 6, the software shall automatically size the system airflow to meet the standard design loads based on a supply-air-to-room-air temperature difference of 20°F, the required ventilation air from Table 120.1-A of the Standard, or makeup air; whichever is greater.  For kitchen MAU systems, the design airflow is the greater of the airflow required to meet the design cooling loads and the total exhaust CFM.

### Terminal Minimum Stop

<i>Applicability</i>	Systems that vary the volume of air at the zone level
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<b>Definition</b>	The minimum airflow that will be delivered by a terminal unit before reheating occurs
<b>Units</b>	Unitless fraction of airflow (cfm) or specific airflow (cfm/ft <sup>2</sup> )
<b>Input Restrictions</b>	This input must be greater than or equal to the outside air ventilation rate.
<b>Standard Design</b>	For systems 5 and 6 set the minimum airflow to be the greater 20% of the peak supply air volume to the zone or the outside air ventilation rate from Table 120.1-A, Section 120.1(e) of the Standards.  For laboratories, the minimum airflow fraction shall be fixed at 1 (100% outside air).

### Terminal Heating Control Type

**Applicability** VAV boxes with reheat

**Definition** The control strategy for the heating mode.

Single Maximum

Dual Maximum: raises the SAT as the first stage of heating, and increases the airflow to the zone as the second stage of heating.

1. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint no larger than 95°F while the airflow is maintained at the dead band flow rate.

2. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate (50% of design flow rate).

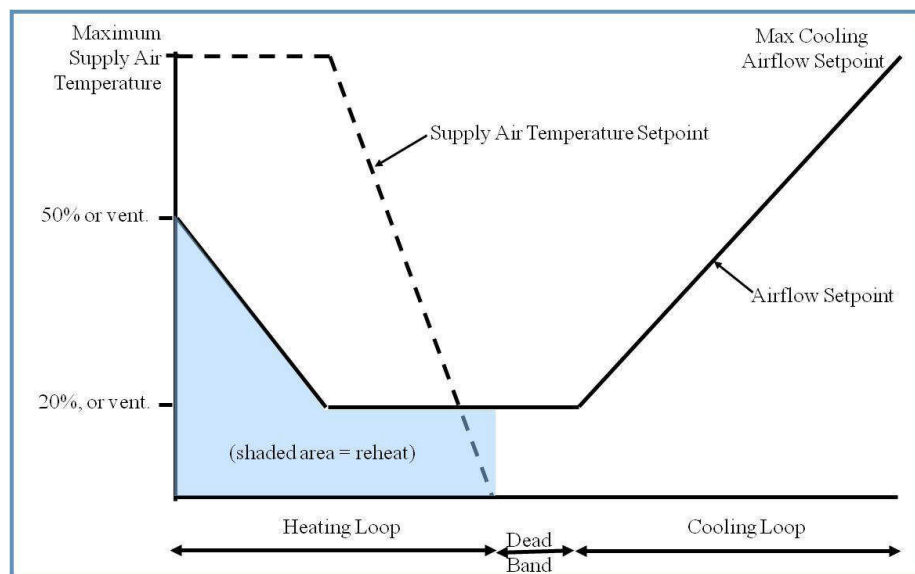


Figure 6 – Dual Maximum Control Sequence

<b>Units</b>	List:  Single Maximum  Dual Maximum
<b>Input Restrictions</b>	Fixed at Single Maximum if Control System Type is not <i>DDC Control to the Zone Level</i>
<b>Standard Design</b>	Dual Maximum

### 5.6.5.2 Fan Powered Boxes

#### Fan Powered Box Type

<i>Applicability</i>	HVAC zones that have fan powered boxes
<i>Definition</i>	Defines the type of fan-powered induction box. This is either: <ul style="list-style-type: none"> <li>• Series; or</li> <li>• Parallel</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Fan Power

<i>Applicability</i>	HVAC zones that have fan powered boxes
<i>Definition</i>	The rated power input of the fan in a fan-powered box.
<i>Units</i>	W or W/cfm
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Fan Powered Box Induced Air Zone

<i>Applicability</i>	HVAC zones that have fan powered boxes
<i>Definition</i>	Zone from which a series or parallel fan-powered box draws its air
<i>Units</i>	List (of zones)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Parallel PIU Induction Ratio

<i>Applicability</i>	HVAC zones that have fan powered boxes
<i>Definition</i>	The ratio of induction-side airflow of a fan-powered box at design heating conditions to the primary airflow
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Parallel Fan Box Thermostat Setpoint

<i>Applicability</i>	HVAC zones that have parallel fan powered boxes
<i>Definition</i>	The temperature difference above the heating setpoint at which the parallel fan is turned on
<i>Units</i>	Degrees Fahrenheit (°F)

<i>Input Restrictions</i>	2°F above the heating setpoint schedule
<i>Standard Design</i>	Not applicable

### 5.6.5.3 Zone Exhaust

This group of building descriptors describes the rate of exhaust and the schedule or control for this exhaust. An exhaust system can serve one thermal zone or multiple thermal zones. Energy is summed for the exhaust system level, not the thermal zone level.

This section also contains unique inputs for kitchen exhaust systems that must meet requirements of section 140.9 of the Standards.

#### **Kitchen Exhaust Hood Length**

<i>Applicability</i>	Exhaust fans in spaces of type Kitchen
<i>Definition</i>	The exhaust hood length
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### **Kitchen Exhaust Hood Style**

<i>Applicability</i>	Exhaust fans in spaces of type Kitchen
<i>Definition</i>	The hood style as defined in Table 140.9-A of the Standards
<i>Units</i>	List: Wall-mounted canopy, Single Island, Double Island, Eyebrow, Backshelf/Passover
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### **Kitchen Exhaust Hood Cooking Duty**

<i>Applicability</i>	Exhaust fans in spaces of type Kitchen
<i>Definition</i>	The hood cooking duty as defined in Table 140.9-A of the Standards
<i>Units</i>	List: Light Duty, Medium Duty, Heavy Duty, Extra Heavy Duty
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### **Exhaust Fan Name**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	A reference to an exhaust fan system that serves the thermal zone
<i>Units</i>	Text or other unique reference to an exhaust fan system defined in the secondary systems section.
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	

Same as the proposed design

#### **Laboratory Exhaust Rate Type**

<i>Applicability</i>	All laboratory zones
<i>Definition</i>	The type of load that dictates lab exhaust rate requirements
<i>Units</i>	List, either: Hood dominated Load dominated
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### **Exhaust Air Flow Rate**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	Rate of exhaust from a thermal zone
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed for non-process zones For laboratory zones, the exhaust air flow rate is prescribed: 15 ACH for hood dominated spaces, or 6 ACH for load dominated spaces
<i>Standard Design</i>	Same as the proposed design for zones that are not of space type Kitchen. For kitchen space types, the baseline is a function of the Kitchen Exhaust Hood Length, Kitchen Exhaust Hood Style and Kitchen Exhaust Hood Cooking Duty, and is determined by Table 140.9-A.

#### **Exhaust Minimum Air Flow Rate**

<i>Applicability</i>	All laboratory zones
<i>Definition</i>	Rate of exhaust from a zone
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed for non-process zones For laboratory zones, the exhaust air flow rate is the maximum of the hood scheduled exhaust air flow rate and the minimum ventilation rate
<i>Standard Design</i>	For laboratory systems, the exhaust minimum air flow rate is the maximum of the hood scheduled exhaust flow rate and 6 ACH, the minimum ventilation rate

#### **Exhaust Fan Schedule**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	Schedule indicating the pattern of use for exhaust air from the thermal zone. This input should consider the position of fume hood sash opening. For toilets and other exhaust applications, the schedule may coincide with the operation of the exhaust fan system.
<i>Units</i>	Data structure: schedule, fraction

**Input Restrictions** As designed for non-process spaces

For laboratory spaces, if the hoods are constant volume the schedule shall be fixed at 0.90 for all hours of the year (24/7).

For laboratory spaces, if the hoods are variable volume the schedule shall be prescribed at:

Hour	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-24
Fraction	0.2	0.3	0.4	0.5	0.7	0.8	0.2	0.5	0.7	0.9	0.8	0.5	0.4	0.3	0.2

**Standard Design** Same as the proposed design for non-process spaces

For kitchen exhaust systems with a flow rate exceeding 5,000 cfm, the standard design schedule shall be as follows:

Hour	1-6	7-9	10	11	12	13	14	15	16	17	18	19	20-24
Fraction	0.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	0.0

For laboratory spaces, the hood exhaust schedule shall be prescribed at:

Hour	1-6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-24
Fraction	0.2	0.3	0.4	0.5	0.7	0.8	0.2	0.5	0.7	0.9	0.8	0.5	0.4	0.3	0.2

#### 5.6.5.4 Outdoor Air Ventilation

##### Ventilation Source

**Applicability** All HVAC zones

**Definition** The source of ventilation for an HVAC system. The choices are:

- Natural (by operable openings)
- Forced (by fan)

**Units** List: natural or forced

**Input Restrictions** For residential units and hotel/motel guest rooms, as designed. For all other occupancies, set to forced.

**Standard Design** For residential units, set to natural, for all other occupancies, set equal to the value for the proposed design.

##### Design Ventilation Rate

**Applicability**

	All HVAC zones
<i>Definition</i>	The quantity of ventilation air that is provided to the space for the specified thermal zone at maximum occupancy
<i>Units</i>	cfm or cfm/occupant
<i>Input Restrictions</i>	As designed, but not lower than code minimum (default value).
	For both compliance and reach, the default value shall be the larger of 15 cfm times the design occupancy from Appendix 5.4A or the conditioned floor area times the applicable ventilation rate from Appendix 5.4A or Table 120.1-A of the Standards. .
<i>Standard Design</i>	The standard design outside air ventilation rate shall be the larger of 15 cfm times the design occupancy from Appendix 5.4A, or the conditioned floor area of the space times the applicable ventilation rate in Appendix 5.4A or Table 120.1-A of the Standards.

#### **Minimum Ventilation Rate**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The minimum quantity of ventilation air that must be provided to the space when it is occupied
<i>Units</i>	cfm or cfm/ft <sup>2</sup>
<i>Input Restrictions</i>	As designed, but not lower than code minimum (default value). The default value shall be the larger of 15 cfm times the design occupancy from Appendix 5.4A or the conditioned floor area times the applicable ventilation rate from Appendix 5.4A or Table 120.1-A of the Standards.
<i>Standard Design</i>	<p>For spaces with demand control ventilation or occupancy sensors, the minimum ventilation rate is specified by the greater of the rate in Table 120.1-A or 15 cfm times the scheduled occupancy for that hour;</p> <p>For systems serving laboratories, the airflow minimum for each lab space shall match those mandated by the Authority Having Jurisdiction.</p> <p>For systems serving kitchens, the minimum outside air ventilation rate is the exhaust air ventilation rate minus available transfer air (available transfer shall be calculated from the building minimum outside airflow less any exhaust airflows other than kitchen exhausts) and minus 0.05 cfm/ft<sup>2</sup> for exfiltration</p> <p>for all other spaces, the minimum ventilation rate is the same as the design ventilation rate in the standard design.</p>

#### **Ventilation Control Method**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	<p>The method used to determine outside air ventilation needed for each hour in the simulation. This information is reported to the system serving the zone. The method of controlling outside air at the system level in response to this information is discussed under secondary systems. Options at the zone level are:</p> <ul style="list-style-type: none"> <li>• Occupant sensors: When the space is occupied, the outside air requirement is equal to the <i>design ventilation rate</i>; otherwise, the outside air requirement is the <i>minimum ventilation rate</i>.</li> </ul>

- CO<sub>2</sub> sensors in the space: The outside air is varied to maintain a maximum CO<sub>2</sub> concentration in the space. This shall be approximated by multiplying the ventilation rate per occupant times the number of occupants for that hour. (When turnstile counts are used to automatically adjust ventilation levels based on occupancy, this method may also be used.)
- Fixed ventilation rate. Outside air is delivered to the zone at a constant rate and is equal to the design ventilation rate (see above).

*Units* List (see above)

*Input Restrictions* As designed

*Standard Design* For Title 24 compliance, if the design occupancy is greater than 25 persons per 1,000 ft<sup>2</sup>, the proposed design has DDC to the zone level or a single zone system with any controls and an outside air economizer, set control method to *CO<sub>2</sub> sensors in the space*, otherwise set to *fixed ventilation rate*.

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## 5.7 HVAC Secondary Systems

This group of building descriptors relate to the secondary HVAC systems. There is not a one-to-one relationship between secondary HVAC system components in the proposed design and the baseline building since the baseline building system is determined from building type, size and heating source. The eight baseline building systems are shown as columns in . The building descriptors are shown as rows and the check marks “✓” indicate that the building descriptor applies for the baseline building system. Depending on the nature of the proposed design, any of the building descriptors could apply.

The HVAC baseline systems are described in the summary tables below for reference. The details of individual building descriptor definitions can be found in subsequent sections 5.7 and 5.8.

Table 15 – System #1 and System #2 Descriptions

System Description:	Packaged Terminal Air Conditioner (#1) or Packaged Terminal Heat Pump (#2)
Supply Fan Power:	N/A (fan power integral to unit efficiency), ventilation provided naturally through operable windows
Supply Fan Control:	Constant volume
Min Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 20F below return air temperature
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum SEER or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp:	$85 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace (#3) or heat pump (#4)
Heating Efficiency:	Minimum AFUE, Thermal Efficiency, COP or HSPF based on equipment type and output capacity of proposed unit(s).
Economizer:	None
Ducts:	N/A (unducted)

Table 16 – System #3 and System #4 Descriptions

System Description:	Packaged Single Zone with Gas Furnace/Electric Air Conditioning (#3) or Heat Pump (#4)
Supply Fan Power:	See Section 5.7.3
Supply Fan Control:	Constant volume
Min Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 20F below return air temperature
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum SEER or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp:	$85 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace (#3) or heat pump (#4)
Heating Efficiency:	Minimum AFUE, Thermal Efficiency, COP or HSPF based on equipment type and output capacity of proposed unit(s).
Economizer:	<b>Integrated economizer</b> with dry-bulb high limit by climate zone, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the compliance software is over 65,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the compliance software is over 2500 cfm
Ducts:	For ducts installed in unconditioned buffer spaces or outdoors as specified in §140.4(l), the duct system efficiency shall be as modified by accounting for duct leakage rate, insulation level and the duct surface area in unconditioned space or outdoors; see applicable building descriptors.

Table 17 – System #5 Description

System Description:	Packaged VAV with Boiler and Reheat
Supply Fan Power:	See Section 5.7.3
Supply Fan Control:	Individual VAV supply fan with less than 10 hp: VAV - forward curved fan with discharge damper
	Individual VAV supply fan greater than or equal to 10 hp: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 20F below return air temperature
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the compliance software is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the compliance software is over 2500 cfm

Table 18 – System #6 Description

System Description:	Chilled Water VAV With Reheat
Supply Fan Power:	See Section 5.7.3
Supply Fan Control:	Individual VAV supply fan with less than 10 hp:: VAV - forward curved fan with discharge damper
	Individual VAV supply fan with greater than or equal to 10 hp: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 20F below return air temperature
Cooling System:	Chilled water
Chilled Water Pumping System	Variable flow (2-way valves) with a VSD on the pump if three or more fan coils or air handlers. Constant volume flow with water temperature reset control if less than three fan coils or air handlers. Reset supply pressure by demand if proposed system has DDC controls.
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve if three or more fan coils or air handlers. Constant volume flow with water temperature reset control if less than three fan coils or air handlers. Reset supply pressure by demand if proposed system has DDC controls.
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the compliance software is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the compliance software is over 2500 cfm

**Table 19 – System #7,8 Description**

System Description:	Single-zone VAV System
Supply Fan Power:	See Section 5.7.3
Supply Fan Control	Two-speed, with fan power at low stage at 40 percent or lower power at 66% flow
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 20F below return air temperature
Supply Temp Control:	Supply temperature setpoint reset up 5°F on low cooling stage. Supply air temperature setpoint shall be linearly reset from minimum at 50% cooling load and above to maximum at 0% cooling load. Fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum air flow at 50% cooling load and below. Minimum fan volume setpoint shall be 50%. (this is effectively an “airflow first” sequence”)
Cooling System:	Direct expansion
Cooling Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Cooling Stages:	Two, with 50% total capacity at low cooling stage
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace or heat pump (system 8)
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve if three or more fan coils. Constant volume flow with water temperature reset control if less than three fan coils. Reset supply pressure by demand if proposed system has DDC controls.
Heating Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Economizer:	Integrated dry bulb economizer with dry-bulb high limit based on climate zone

**Table 20 – System #9 Description**

System Description:	Heating and ventilation only system
Supply Fan Power:	See fan power details; 0.8 W/cfm baseline
Supply Fan Control	Constant Volume
Minimum Supply Temp:	N/A
Cooling System:	None
Cooling Efficiency:	N/A
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace
Hot Water Pumping System	N/A
Heating Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Economizer:	TBD

**Table 21 – System #10 Description**

System Description:	Computer room air handler (CRAH)
Supply Fan Power:	See fan power details; 0.49 W/cfm baseline
Supply Fan Control	variable speed drive. Fan power ratio at part load = speed ratio ^3 (e.g. 12.5% of design power at 50% speed).
Minimum Supply Temp:	60F
Cooling System:	Chilled water
Cooling Efficiency:	Same as System #6 (Built-up VAV)
Maximum Supply Temp:	80
Heating System:	None
Economizer:	TBD
Supply Temp Control:	Supply air temperature setpoint shall be linearly reset from minimum at 50% cooling load and above to maximum at 0% cooling load. Fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum air flow at 50% cooling load and below. Minimum fan volume setpoint shall be 50%. (this is effectively an “airflow first” sequence”)

Table 22 – System #11 Description

System Description:	Computer room air conditioner (CRAC)
Supply Fan Power:	0.49 W/cfm at design flow (see equipment sizing) where economizer is required, 0.39 W/cfm where economizer is not required.
Supply Fan Control	Constant speed if total cooling capacity for the room < = 5 tons, otherwise: variable speed drive. Fan power ratio at part load = speed ratio ^3 (e.g. 12.5% of design power at 50% speed).
Return Fan Control:	No return fans
Minimum Supply Temp:	60F
Cooling System:	Air-cooled DX
Cooling Capacity:	Equipment sizing CFM and cooling capacity sized at 120% of the calculated room load. One fan system per room.
Cooling Efficiency:	Minimum packaged air conditioner efficiency based on calculated total cooling capacity for each room <ul style="list-style-type: none"> <li>• If cooling capacity &gt; 20 tons then use 10 ton min efficiency</li> <li>• If cooling capacity &lt;20 tons then use capacity/2 min efficiency</li> </ul>
Maximum Supply Temp:	80
Heating System:	None
Economizer:	No economizer if total cooling capacity for the room < 5 tons and building does not have any economizers, otherwise: Integrated differential dry bulb economizer
Supply Temp Control:	<b>VAV:</b> Supply air temperature setpoint shall be linearly reset from minimum at 50% cooling load and above to maximum at 0% cooling load. Fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum air flow at 50% cooling load and below. Minimum fan volume setpoint shall be 50%. (this is effectively an "airflow first" sequence) <b>CV:</b> supply air temperature setpoint modulates to meet the load.

### 5.7.1 Basic System Information

#### HVAC System Name

<i>Applicability</i>	All system types A unique descriptor for each HVAC System
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	When applicable, this input should match the tags that are used on the plans.
<i>Standard Design</i>	None

#### System Type

<i>Applicability</i>	All system types
<i>Definition</i>	A unique descriptor which identifies the following attributes of an HVAC System: <ul style="list-style-type: none"> <li>• Number of air decks (one to three);</li> <li>• Constant or variable air flow;</li> <li>• Type of terminal device; and</li> <li>• Fan configuration for multiple deck systems.</li> </ul>
<i>Units</i>	List from the choices below
<i>Input Restrictions</i>	List

PTAC – Packaged Terminal Air Conditioner  
 PTHP – Packaged Terminal Heat Pump  
 PSZ-AC – Packaged Single Zone  
 PSZ-HP – Packaged Single Zone Heat Pump  
 PVAV – Packaged VAV with Reheat  
 VAV – VAV with Reheat  
 PSZVAV – Single Zone VAV  
 PSZVAVHP – Single Zone VAV Heat Pump  
 HV – Heating and Ventilation Only  
 CRAC – Computer Room Air Conditioner  
 CRAH – Computer Room Air Handler  
 FPFC – Four-pipe fan coil  
 DFDD – Dual-fan dual duct  
 RADFLR – Radiant floor heating and cooling  
 CHB – Chilled beam  
 UFAD – Underfloor air distribution  
 DV – displacement ventilation  
 WSHP – water-source heat pump  
 GSHP – ground-source heat pump  
 VRF – variable refrigerant flow

*Standard Design* Based on the prescribed system type in the HVAC system map (see *Table 6 – HVAC System Descriptions*). The baseline system types are shown in the table below.

**Table 23 – Baseline Building System Type**

Baseline Building System Type

System 1 – PTAC
System 2 – FPFC
System 3 – PSZ-AC
System 5 – Packaged VAV with Reheat
System 6 – VAV with Reheat
System 7 – PSZ-SZVAV
System 9 – Heating and Ventilation
System 10 – CRAC Unit
System 11 – CRAH Unit

#### **Air Distribution Type**

*Applicability* All system types

*Definition* Type of air distribution system that is coupled with the HVAC system. The choices are (overhead) mixing ventilation system, underfloor air distribution system (UFAD), and displacement ventilation system (DV).

<i>Units</i>	List: Mixing, UFAD, DV
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Mixing

#### **Thermal zone List**

<i>Applicability</i>	All system types
<i>Definition</i>	Comprehensive list of all thermal zones served by a given HVAC system.
<i>Units</i>	None
<i>Standard Design</i>	Same as the proposed design
<i>Input Restrictions</i>	As designed

#### **Total Cooling Capacity**

<i>Applicability</i>	All system types
<i>Definition</i>	The installed cooling capacity of the project. This includes all: <ul style="list-style-type: none"> <li>• Chillers;</li> <li>• Built-up DX; and,</li> <li>• Packaged cooling units.</li> </ul>
<i>Units</i>	Cooling tons (12,000 Btu/h per ton)
<i>Input Restrictions</i>	As designed. This could be calculated by the program from the proposed design building description or a separate load calculation may be used. Unmet load hours for the simulation shall not exceed 300 annually. Weather conditions used in sizing runs shall be based on 0.5% dry-bulb and 1% wet-bulb cooling design temperatures.
<i>Standard Design</i>	Autosize. The cooling capacity shall be oversized by 15%. If the number of unmet load hours exceeds 300, increase the cooling capacity according to the procedures in Chapter 2.

## **5.7.2 System Controls**

### **5.7.2.1 Schedules**

#### **Cooling Schedule**

<i>Applicability</i>	All cooling systems
<i>Definition</i>	A schedule that represents the availability of cooling
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	For California Compliance and Reach calculations, the fan schedules from Appendix 5.4B shall be used as a default for cooling availability. When schedules other than the default values are used, supporting documentation shall be required. The cooling availability schedule shall be consistent with the supply fan schedule and thermostat schedules to reduce the likelihood of unmet load hours.
<i>Standard Design</i>	Same as the proposed design

**Heating Schedule**

<i>Applicability</i>	All systems
<i>Definition</i>	A schedule that represents the availability of heating
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	For California Compliance and Reach calculations, the schedules from Appendix 5.4B shall be used as a default. When schedules other than the default values are used, supporting documentation shall be required. The heating availability schedule shall be consistent with the supply fan schedule.
<i>Standard Design</i>	Same as the proposed design

**Air-Handler Schedule**

<i>Applicability</i>	All systems that do not cycle with loads
<i>Definition</i>	A schedule that indicates when the air handler operates continuously
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	For the purpose of Compliance and Reach calculations, the fan schedule is defaulted to the applicable schedule from Appendix 5.4B. One of the schedules from Appendix 5.4B, shall be used as a default. When schedules other than the default values are used, supporting documentation shall be required.  When a fan system serves several occupancies, the fan schedule must remain ON to serve the operating hours of each occupancy.
<i>Standard Design</i>	Same as the proposed design

**Air Handler Fan Cycling**

<i>Applicability</i>	All fan systems
<i>Definition</i>	This building descriptor indicates whether the system supply fan operates continuously or cycles with building loads. The fan systems in most commercial buildings operate continuously.
<i>Units</i>	List: Continuous or Cycles with loads
<i>Input Restrictions</i>	Continuous fan operation during occupied periods is a prescribed input  For natural ventilation systems, an air conditioner is modeled in the proposed design even though one is not specified for the proposed design. In this case, the air handler control is <i>Cycles with loads</i> . .
<i>Standard Design</i>	Same as proposed design

**Optimal Start Control**

<i>Applicability</i>	Systems with the control capability for flexible scheduling of system start time based on building loads.
<i>Definition</i>	Optimal start control adjusts the start time of the HVAC unit such that the space is brought to setpoint just prior to occupancy. This control strategy modifies the heating, cooling, and fan schedules.
<i>Units</i>	Boolean (Yes/No)
<i>Input Restrictions</i>	No (not allowed)
<i>Standard Design</i>	applicable

**Night-Cycle HVAC Fan Control**

<i>Applicability</i>	All systems
<i>Definition</i>	The control of an HVAC system that is triggered by the heating or cooling temperature setpoint for thermal zones during periods when the heating, cooling and fan systems are scheduled to be off. For this control, the space is controlled to the setback or setup temperature only; this control is not equivalent to a night purge control. The choices are: <ul style="list-style-type: none"> <li>• Cycle on call from any zone</li> <li>• Cycle on call from the primary control zone</li> <li>• Stay off</li> <li>• Cycle zone fans only (for systems with fan-powered boxes) Restart fans below given ambient temperature.</li> </ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. Outside air dampers are set to closed during night-cycle control.
<i>Standard Design</i>	Same as proposed

**5.7.2.2 Cooling Control****Cooling Supply Air Temperature**

<i>Applicability</i>	Applicable to all systems
<i>Definition</i>	The supply air temperature setpoint at design cooling conditions
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	15F below the space temperature setpoint for interior zones; for all other zones, 20°F below the space temperature setpoint

**Cooling Supply Air Temperature Control**

<i>Applicability</i>	Any cooling system
<i>Definition</i>	The method of controlling the supply air temperature. Choices are: <ul style="list-style-type: none"> <li>• Fixed (constant)</li> <li>• Reset by warmest zone</li> <li>• Reset by outside air dry-bulb temperature</li> <li>• Scheduled setpoint</li> <li>• Staged setpoint (for Single Zone VAV and DX with multiple stages)</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	
<i>Standard Design</i>	For baseline building systems 1 through 4 and 11, the SAT control is fixed. For systems 5 through 8 and 10, the SAT control shall be reset by warmest zone. For system 9 (heating and ventilation) this input is not applicable.

**Cooling Reset Schedule by OSA**

<i>Applicability</i>	When the proposed design resets SAT by outside air dry-bulb temperature
<i>Definition</i>	<p>A linear reset schedule that represents the SAT setpoint as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points (see Figure 7):</p> <ul style="list-style-type: none"> <li>• The coldest cooling supply air temperature</li> <li>• The corresponding (hot) outdoor air dry-bulb setpoint</li> <li>• The warmest cooling supply air temperature</li> <li>• The corresponding (cool) outdoor air dry-bulb setpoint</li> </ul>

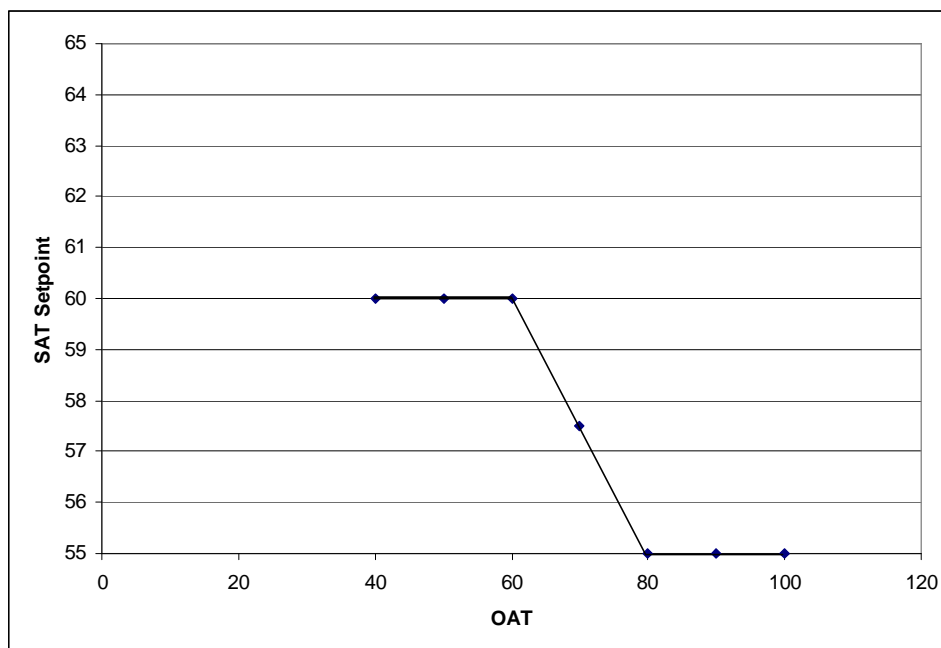


Figure 7 – SAT Cooling Setpoint Reset based on Outdoor Air Temperature (OAT)

<i>Units</i>	Data structure (two matched pairs of SAT and OAT, see above)
<i>Input Restrictions</i>	<p>As Designed.</p> <p>For California Compliance and Reach, the schedule defaults to:</p> <p>Supply Air High = Supply Air Low + 5</p> <p>Supply Low = (greater of SAT and 50F)</p> <p>Outside High = 80°F</p> <p>Outside Low = 60°F</p>
<i>Standard Design</i>	Applicable for baseline building systems 5 and 6. For these systems, the minimum SAT shall be equal to the design conditions SAT when OAT is equal to or greater than 80 F. The maximum SAT shall be 5 F greater than the minimum when the OAT is 60 F or less.

### 5.7.2.3 Heating Control

#### Preheat Setpoint

<i>Applicability</i>	Systems with a preheat coil located in the outside air stream
<i>Definition</i>	The control temperature leaving the preheat coil
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not Applicable

#### Heating Supply Air Temperature

<i>Applicability</i>	All systems
<i>Definition</i>	The supply air temperature leaving the air handler when the system is in a heating mode (not the air temperature leaving the reheat coils in VAV boxes)
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	105°F for system types 1-4; 70°F for system types 5 and 6; except 80°F for systems serving data centers

#### Heating Supply Air Temperature Control

<i>Applicability</i>	Systems with the capability to vary heating SAT
<i>Definition</i>	The method of controlling heating SAT. Choices are: <ul style="list-style-type: none"> <li>• Fixed (constant)</li> <li>• Reset by coldest zone</li> <li>• Reset by outside air dry-bulb temperature</li> <li>• Scheduled setpoint</li> </ul>
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Fixed (constant)

#### Heating Reset Schedule by OSA

<i>Applicability</i>	Systems that reset the heating SAT by outside dry-bulb temperature (this typically applies to dual-duct systems or to single zone systems with hydronic heating coils)
<i>Definition</i>	A linear reset schedule that represents the heating supply air temperature or hot deck supply air temperature (for dual duct systems) as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points (see Figure 8): <ul style="list-style-type: none"> <li>• The hottest heating supply air temperature</li> <li>• The corresponding (cold) outdoor air dry-bulb threshold</li> <li>• The coolest heating supply air temperature</li> <li>• The corresponding (mild) outdoor air dry-bulb threshold</li> </ul>

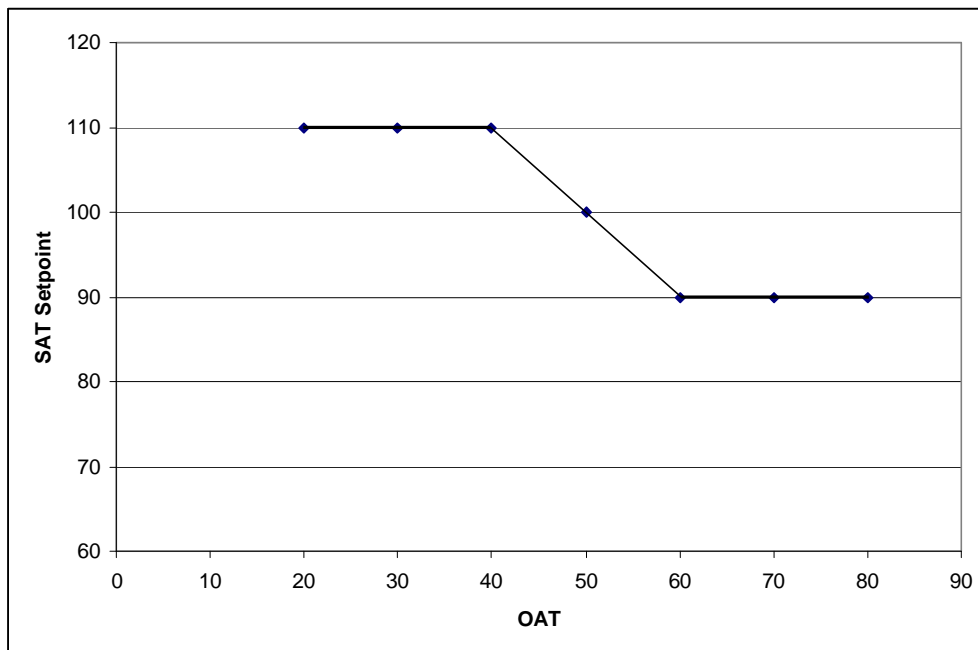


Figure 8 – Example of SAT heating setpoint reset based on outdoor air temperature (OAT).

<i>Units</i>	Data structure (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### 5.7.2.4 Night Purge

Night purge controls are not allowed for Title 24 compliance or reach.

##### Night Purge Availability Schedule

<i>Applicability</i>	Systems that operate the fans for nighttime purge of heat gains
<i>Definition</i>	A schedule which represents the availability of night purge controls.
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	Not applicable
<i>Standard Design</i>	Not applicable

##### Night Purge Control

<i>Applicability</i>	Systems that operate the fans for nighttime purge of heat gains
<i>Definition</i>	The control strategy for operation of nighttime purge. The control strategy may take account of indoor temperature, season, indoor temperature and other factors.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	Not applicable (Night Purge Control is not allowed in the model)
<i>Standard Design</i>	Not applicable

**Night Purge Fan Ratio**

<i>Applicability</i>	Systems that operate the fans for nighttime purge of heat gains
<i>Definition</i>	The ratio of fan speed for a night purge cycle.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	Not applicable
<i>Standard Design</i>	Not applicable

**5.7.3 Fan Systems****5.7.3.1 Baseline Building Fan System Summary**

The baseline building fan system is summarized in this section. See Table 5 – HVAC System Map for the HVAC baseline building system mapping.

Total baseline building fan system power for the baseline building fan systems is given in the following section. This brake horsepower includes the supply fan, the return fan, and exhaust fans. Exhaust fans include kitchen hoods, toilets, fume hoods, and other miscellaneous fans that operate at design conditions.

When the proposed design has exhaust fans (toilets or kitchens), or fume hood exhaust systems, the baseline building has the same systems.

*Table 24 – Building Descriptor Applicability for Fan Systems*

<b>Inputs</b>	<b>Supply Fan</b>	<b>Return/Relief Fan</b>	<b>Exhaust Fans (Hoods)</b>
Modeling Method	✓	Same as supply	✓
Air Rated Capacity	✓	✓	✓
Plenum Zone	X	✓	X
Return Air Path	X	✓	X
Fan Control Method	✓	Same as supply	✓
Brake Horsepower	✓	✓	✓
Static Pressure	✓	✓	✓
Fan Efficiency	✓	✓	✓
Motor Efficiency	✓	✓	✓
Fan Position	✓	X	X
Motor Position	✓	✓	X
Part-Load Power Curve	✓	✓	✓
Fan KW	✓	✓	✓

**5.7.3.2 Supply Fans****Fan System Modeling Method**

<i>Applicability</i>	All fan systems
<i>Definition</i>	Software commonly models fans in three ways. The simple method is for the user to

enter the electric power per unit of flow (W/cfm). This method is commonly used for unitary equipment and other small fan systems. A more detailed method is to model the fan as a system whereby the static pressure, fan efficiency, part-load curve, and motor efficiency are specified at design conditions. A third method is to specify brake horsepower at design conditions instead of fan efficiency and static pressure. This is a variation of the second method whereby brake horsepower is specified in lieu of static pressure and fan efficiency. The latter two methods are commonly used for VAV and other larger fan systems.

<i>Units</i>	List: power-per-unit-flow, static pressure or brake horsepower
<i>Input Restrictions</i>	As designed. The power-per-unit-flow method shall be used when no fan performance data is available for the proposed design cooling system, e.g. only EER or SEER are available.
<i>Standard Design</i>	The baseline building shall use the static pressure method.

### **Supply Fan Design Air Rated Capacity**

<i>Applicability</i>	All fan systems
<i>Definition</i>	The design air flow rate of the supply fan(s) at design conditions. This building descriptor sets the 100% point for the fan part-load curve.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed. This input should be at least as great as the sum of the design air flow specified for each of the thermal zones that are served by the fan system. For multiple deck systems, a separate entry should be made for each deck.
<i>Standard Design</i>	The program shall automatically size the air flow at each thermal zone to meet the loads. The design air flow rate calculation shall be based on a 20°F temperature differential between the supply air and the return air for exterior zones and a 15°F temperature differential for interior zones. The design supply air flow rate is the larger of the flow rate required to meet space conditioning requirements and the required ventilation flow rate. (The ventilation requirements may dictate supply air flow rate requirements for laboratory spaces and other spaces with special process requirements.) The supply fan design air flow rate shall be the sum of the calculated design air flow for the thermal zones served by the fan system.

### **Fan Control Method**

<i>Applicability</i>	All fan systems
<i>Definition</i>	<p>A description of how the supply (and return/relief) fan(s) are controlled. The options include:</p> <ul style="list-style-type: none"> <li>• Constant volume</li> <li>• Variable-flow, inlet or discharge dampers</li> <li>• Variable-flow, inlet guide vanes</li> <li>• Variable-flow, variable speed drive (VSD)</li> <li>• Variable-flow, variable pitch blades</li> <li>• Variable-flow, other</li> <li>• Two-speed</li> <li>• Constant volume, cycling (fan cycles with heating and cooling)</li> </ul>
<i>Units</i>	

	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Applicable to variable air volume systems
	Based on the prescribed system type. Refer to the HVAC System Map in <b>Error!</b> <b>Reference source not found..</b>

**Table 25 – Baseline Building Fan Control Method**

Baseline building System	Fan Control Method
System 1 – PTAC	Constant volume (Two-speed for systems greater than 72 kBtu/h baseline cooling capacity)
System 2 – PTHP	Constant volume (Two-speed for systems greater than 72 kBtu/h baseline cooling capacity,)
System 3 – PSZ-AC	Constant volume (Two-speed for systems greater than 72 kBtu/h baseline cooling capacity,)
System 4 – PSZ-HP	Constant volume(Two-speed for systems greater than 72 kBtu/h baseline cooling capacity)
System 5 – Packaged VAV with Reheat	Variable-flow, variable speed drive (VSD)
System 6 – VAV with Reheat	Variable-flow, variable speed drive (VSD)
System 7 – PSZ, Single Zone VAV	Variable-flow, two-speed drive (VSD)
System 8 – PSZ, Single Zone VAV, HP	Variable-flow, two-speed drive (VSD)
System 9 – Heating and Ventilation	Constant volume
System 10 – CRAH Units	Variable-flow, variable speed drive (VSD)*
System 11 – CRAC Units	Variable-flow, variable speed drive (VSD)*

**\* For CRAH Units, fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum airflow at 50% cooling load and below.**

**Supply Fan Brake Horsepower**

<i>Applicability</i>	All fan systems, except those specified using the power-per-unit-flow method
<i>Definition</i>	The design shaft brake horsepower of the supply fan(s). This input does not need to be supplied if the Supply Fan kW is supplied.
<i>Units</i>	Horsepower (hp)
<i>Input Restrictions</i>	As designed. If this building descriptor is specified for the proposed design, then the <i>Static Pressure</i> and <i>Fan Efficiency</i> are not.  Series-powered fans that operate at design conditions should be included in the proposed fan brake horsepower calculations. Fans for parallel fan-powered boxes are not included.
<i>Standard Design</i>	Not applicable

**Supply Fan Static Pressure**

<i>Applicability</i>	All fan systems, except those specified using the power-per-unit-flow method
<i>Definition</i>	The design static pressure for the supply fan. This is important for both fan electric energy usage and duct heat gain calculations.
<i>Units</i>	Inches of water column (in. H <sub>2</sub> O)
<i>Input Restrictions</i>	

As designed. The design static pressure for the supply fan does not need to be specified if the supply fan brake horsepower (bhp) is specified.

**Standard Design** Not applicable. When *Static Pressure* and *Fan Efficiency* are entered for the proposed design, the baseline building shall use *Brake Horsepower*.

The standard design is defined by the following table:

Airflow	Single Zone, 6 stories or less	Single Zone, 6 stories or less	Multiple Zone, less than 6 stories	Multiple Zone, greater than 6 stories
<2000 cfm	2.5"	3.0"	3.0"	3.5"
2000 cfm – 10,000 cfm	3.0"	3.5"	3.5"	4.0"
>10,000 cfm	3.5"	4.0"	4.0"	4.5"

An additional pressure drop allowance is available for special filtration requirements only for specific processes such as clean rooms. See *Process and Filtration Pressure Drop* for details.

### Supply Fan Efficiency

**Applicability** All fan systems, except those specified using the power-per-unit-flow method

**Definition** The efficiency of the fan at design conditions; this is the static efficiency and does not include motor losses.

**Units** Unitless

**Input Restrictions** As designed. The supply fan efficiency does not need to be specified if the supply fan brake horsepower (bhp) is specified.

**Standard Design**

The baseline Supply Fan Efficiency shall be 50% if the design supply air flow is less than 2000 cfm, 60% if the design supply air flow is between 2000 cfm and 10,000 cfm, or 62% if the design supply airflow is greater than 10,000 cfm.

### Supply Motor Efficiency

**Applicability** All supply fans, except those specified using the power-per-unit-flow method

**Definition** The full-load efficiency of the motor serving the supply fan

**Units** Unitless

**Input Restrictions** As designed. Not applicable when the power-per-unit-flow method is used.

**Standard Design** The motor efficiency is determined from Table 26 for the next motor size greater than the bhp.

Table 26 – Minimum Nominal Efficiency for Electric Motors (%)

Motor Horse Power	
1	85.5
1.5	86.5
2	86.5
3	89.5
5	89.5
7.5	91.7
10	91.7
15	92.4
20	93.0
25	93.6
30	93.6
40	94.1
50	94.5
60	95.0
75	95.4
100	95.4
125	95.4
150	95.8
200	96.2
250	96.2
300	96.2
350	96.2
400	96.2
450	96.2
500	96.2

**Fan Position**

<i>Applicability</i>	All supply fans
<i>Definition</i>	The position of the supply fan relative to the cooling coil. The configuration is either draw through (fan is downstream of the coil) or blow through (fan is upstream of the coil).
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Draw through

**Motor Position**

<i>Applicability</i>	All supply fans
<i>Definition</i>	The position of the supply fan motor relative to the cooling air stream. The choices are: in the air stream or out of the air stream.
<i>Units</i>	List (see above)

<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	In the air stream

**Fan Part-Flow Power Curve**

<i>Applicability</i>	All variable flow fan systems
<i>Definition</i>	A part-load power curve which represents the percentage full-load power draw of the supply fan as a function of the percentage full-load air flow. The curve is typically represented as a quadratic equation with an absolute minimum power draw specified.
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	As designed. The user shall not be able to select VSD with Static Pressure Reset if the building does not have DDC controls to the zone level. The default fan curve shall be selected from Equation (4) and Table 27 for the type of fan specified in the proposed design.

(4)

Greater of

$$PLR = a + b \cdot FanRatio + c \cdot FanRatio^2 + d \cdot FanRatio^3$$

$$PLR = PowerMin$$

where

PLR	Ratio of fan power at part load conditions to full load fan power
PowerMin	Minimum fan power
FanRatio	Ratio of cfm at part-load to full-load cfm
a, b, c and d	Constants from Table 27 below

**Table 27 – Fan Curve Default Values**

Fan Type - Control Type	A	B	c	d	%Power <sub>Min</sub>
AF or BI riding the curve <sup>a</sup>	0.1631	1.5901	-0.8817	0.1281	70%
AF or BI with inlet vanes <sup>a</sup>	0.9977	-0.659	0.9547	-0.2936	50%
FC riding the curve <sup>a</sup>	0.1224	0.612	0.5983	-0.3334	30%
FC with inlet vanes <sup>a</sup>	0.3038	-0.7608	2.2729	-0.8169	30%
Vane-axial with variable pitch blades <sup>a</sup>	0.1639	-0.4016	1.9909	-0.7541	20%
Any fan with VSD ( ) <sup>b</sup>	0.0013	0.1470	0.9506	-0.0998	20%
VSD with static pressure reset <sup>c</sup>	-0.0031	0.0991	1.0268	-0.1128	20%

Data Sources:

a. ECB Compliance Supplement, public review draft, Version 1.2, March 1996, but adjusted to be relatively consistent with the curve specified in the PRM.

b. The fan curve for VSD is specified in Table G3.1.3.15

c. Advanced VAV System Design Guide, California Energy Commission, CEC Publication 500,-03-082 A-11, April 2005, but adjusted to be relatively consistent with the curve specified in the PRM..

<i>Standard Design</i>	Not applicable for baseline building systems 1-4. The curve <i>VSD with static pressure reset</i> fans shall be used for baseline building systems 5, 6, 10 and 11 . For systems 7,8 and 9 the baseline is not applicable.
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**Supply Fan Power Index**

<i>Applicability</i>	Fan systems that use the power-per-unit-flow method
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<i>Definition</i>	The supply fan power per unit of flow.
<i>Units</i>	kW/cfm
<i>Input Restrictions</i>	As designed or specified in the manufacturers' literature. For units with rated total cooling capacities less than 120,000 Btu/h, the user may default to a value calculated as follows:

(5)

$$Fan_{kw} = 0.365 \times \frac{Q_{rated}}{30,000}$$

where

Fan<sub>kw</sub> The supply fan power (kW)Q<sub>rated</sub> The rated total cooling capacity (Btu/h)

<i>Standard Design</i>	Not applicable
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**Process and Filtration Pressure Drop**

<i>Applicability</i>	Any system with special requirements for filtration or other process requirements
<i>Definition</i>	Additional system pressure drop related to application-specific filtration requirements or other process requirements. Special documentation requirements may apply.
<i>Units</i>	List
<i>Input Restrictions</i>	Default is 0. Special documentation is required to claim any credit for filtration or other process requirements. Filtration shall be associated with process requirements (such as clean room or hospital areas).
<i>Standard Design</i>	0 (not applicable)

**5.7.3.3 Return/Relief Fans**

The baseline building has a return fan when the baseline building system is type 3 through 8 and the proposed design has a return fan.

**Plenum Zone**

<i>Applicability</i>	Any system with return ducts or return air plenum
<i>Definition</i>	A reference to the thermal zone that serves as return plenum or where the return ducts are located
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Applicable when the baseline building has a return fan. Same as the proposed design when the proposed design has a plenum, otherwise, the return air ducts are assumed to be located in the space.

**Return Air Path**

<i>Applicability</i>	Any system with return ducts or return air plenum
<i>Definition</i>	

	Describes the return path for air. This can be one of the following: ducted return; plenum return; or direct-to-unit.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Applicable when the baseline building has a return fan. For baseline building systems 1 and 2, the return air path shall be direct-to-unit. For baseline building systems 3 through 11 and when the proposed design is direct-to-unit, the baseline building shall be ducted return, otherwise the baseline building return air path shall be same as proposed design.

#### **Return/Relief Air Rated Capacity**

<i>Applicability</i>	All systems with a return or relief fan
<i>Definition</i>	The design air flow fan capacity of the return or relief fan(s). This sets the 100% fan flow point for the part-load curve (see below).
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Applicable when the baseline building has a return fan. The return fan air <i>Rated Capacity</i> shall be equal to the baseline building supply fan capacity less exhaust air flow.

#### **Return/Relief Fan Brake Horsepower**

<i>Applicability</i>	Any system with return or relief fans that uses the brake horsepower method
<i>Definition</i>	The design shaft brake horsepower of the return/relief fan(s)
<i>Units</i>	Brake horsepower (bhp)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The bhp of the return fan shall be the system fan power index (W/cfm) multiplied by the supply airflow, the motor efficiency from ACM Table N2-20, and the return fan ratio. In other words, brake horsepower is allocated in proportion to the proposed design.

#### **Return/Relief Design Static Pressure**

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
<i>Definition</i>	The design static pressure for return fan system. This is important for both fan electric energy usage and duct heat gain calculations.
<i>Units</i>	Inches of water column (in. H <sub>2</sub> O gauge)
<i>Input Restrictions</i>	As designed. The design static pressure for the return fan does not need to be specified if the return fan brake horsepower (bhp) is specified.
<i>Standard Design</i>	For fans with design airflow less than 10,000 cfm, the static pressure is 0.75". For fans with design airflow rate 10,000 cfm or greater, the static pressure is 1.0"

#### **Return/Relief Fan Efficiency**

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
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<i>Definition</i>	The efficiency of the fan at design conditions; this is the static efficiency and does not include the efficiency loss of the motor.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. The return/relief fan efficiency does not need to be specified if the return fan brake horsepower (bhp) is specified.
<i>Standard Design</i>	Not applicable. When <i>Static Pressure</i> and <i>Fan Efficiency</i> are entered for the proposed design, the baseline building shall use <i>Brake Horsepower</i> .  For design airflow less than 10,000 cfm, 40%. For design airflow 10,000 cfm or greater, 50%.

**Return/Relief Motor Efficiency**

<i>Applicability</i>	All return fans, except those specified using the power-per-unit-flow method
<i>Definition</i>	The full-load efficiency of the motor serving the supply fan
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. Not applicable when the power-per-unit-flow method is used.
<i>Standard Design</i>	From ACM Table 26

**Motor Position**

<i>Applicability</i>	All return fans
<i>Definition</i>	The position of the supply fan motor relative to the cooling air stream. The choices are: in the air stream or out of the air stream.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	In the air stream

**Fan Part-Flow Power Curve**

<i>Applicability</i>	All return fans for variable flow fan systems.
<i>Definition</i>	A part-load power curve which represents the percentage full-load power draw of the supply fan as a function of the percentage full-load air flow.
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	As designed. The default fan curve shall be selected from Equation (4) and Table 27 for the type of fan specified in the proposed design.
<i>Standard Design</i>	Not applicable for baseline building systems 1-4. The curve for VSD fans shall be used for baseline building systems 5-6, and 10 or 11 that have a return/relief fan. This is not applicable for baseline building systems 7, 8, 9.

**Return/Relief Fan Power Index**

<i>Applicability</i>	Any system with a return fan
<i>Definition</i>	The supply fan power per unit of flow
<i>Units</i>	kW/cfm
<i>Input Restrictions</i>	As specified in the manufacturers' literature
<i>Standard Design</i>	

Not applicable

#### 5.7.3.4 Exhaust Fan Systems

Exhaust fans include toilet exhaust and kitchen exhaust. Fume hoods in laboratories and other spaces are not included. Some systems typically operate at constant flow, while flow varies for other systems depending on, for instance, the position of the sash for fume hoods. Exhaust fan flow is specified and scheduled for each thermal zone. An exhaust fan system may serve multiple thermal zones. The baseline building has exhaust fans when the proposed design has exhaust fans. The exhaust air flow is the same for the baseline building and the proposed design.

Note: exhaust fans serving laboratories shall be modeled as a plug load in an unconditioned space equal to the scheduled motor horsepower of the exhaust fans.

##### Exhaust Fan Name

<i>Applicability</i>	All exhaust systems serving multiple thermal zones
<i>Definition</i>	A unique descriptor for each exhaust fan. This should be keyed to the construction documents, if possible, to facilitate plan checking. Exhaust rates and schedules at the thermal zone level refer to this name.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans.
<i>Standard Design</i>	The baseline building will have an exhaust system that corresponds to the proposed design. The name can be identical to that used for the proposed design or some other appropriate name may be used.

##### Exhaust Fan System Modeling Method

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	Software commonly models fans in three ways. See definition for supply system modeling method.
<i>Units</i>	List: power-per-unit-flow, static pressure or brake horsepower
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline building shall use the static pressure method.

##### Exhaust Fan Rated Capacity

<i>Applicability</i>	All exhaust systems
<i>Definition</i>	The rated design air flow rate of the exhaust fan system. This building descriptor defines the 100% flow case for the part-flow curve. Actual air flow is the sum of the flow specified for each thermal zone, as modified by the schedule for each thermal zone.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as proposed design

##### Fan Control Method

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	

	A description of how the exhaust fan(s) are controlled. The options include: <ul style="list-style-type: none"> <li>• Constant volume</li> <li>• Two-speed</li> <li>• Variable-flow, inlet or discharge dampers</li> <li>• Variable-flow, inlet guide vanes</li> <li>• Variable-flow, variable speed drive (VSD)</li> <li>• Variable-flow, variable pitch blades</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed, however, when exhaust fan flow at the thermal zone level is varied through a schedule, one of the variable-flow options shall be specified.
<i>Standard Design</i>	The baseline building exhaust fan control shall generally be the same as the proposed design.

#### **Exhaust Fan Schedule**

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	A schedule that indicates when the exhaust fan system is available for operation. Exhaust fan flow is specified at the thermal zone level.
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Same as the proposed design for exhaust fans not serving Kitchen spaces.  For exhaust fans serving kitchen spaces, the fan control method is constant volume for fans with flow rate 5,000 cfm and below, and variable flow, variable speed drive for fans with flow rate greater than 5,000 cfm.

#### **Exhaust Fan Brake Horsepower**

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	The design shaft brake horsepower of the exhaust fan(s).
<i>Units</i>	Brake horsepower (bhp)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### **Exhaust Fan Design Static Pressure**

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
<i>Definition</i>	The design static pressure for exhaust fan system. This is important for both fan electric energy usage and duct heat gain calculations.
<i>Units</i>	Inches of water column (in. H <sub>2</sub> O)
<i>Input Restrictions</i>	As designed for exhaust fans not serving kitchens. The design static pressure for the exhaust fan does not need to be specified if the exhaust fan brake horsepower (bhp) is specified.

	For kitchen exhaust fans, the static pressure is fixed at 2.5" w.c.
<i>Standard Design</i>	For kitchen exhaust fans, the static pressure is fixed at 2.5" w.c. For all other exhaust fans, For toilet exhaust fans: 0.75" if less than 1000 cfm, 1.25" if 1000 cfm or greater. For lab exhaust, 4" if 6 stories or less, or 4.5" if greater than 6 stories.

**Exhaust Fan Efficiency**

<i>Applicability</i>	Any exhaust fan system that uses the static pressure method
<i>Definition</i>	The efficiency of the exhaust fan at rated capacity; this is the static efficiency and does not include losses through the motor.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	For kitchen exhaust fans, the fan efficiency is prescribed at 50%. For all other exhaust fans, as designed. The exhaust fan efficiency does not need to be specified if the return fan brake horsepower (bhp) is specified.
<i>Standard Design</i>	For kitchen exhaust fans, the fan efficiency is 50%.  For toilet exhaust, 45% if the design airflow is less than 1000 cfm, and 55% if 1000 cfm or greater. For lab exhaust, 62%.

**Exhaust Fan Motor Efficiency**

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	The full-load efficiency of the motor serving the exhaust fan
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	From Table 27

**Fan Part-Flow Power Curve**

<i>Applicability</i>	All variable flow exhaust fan systems
<i>Definition</i>	A part-load power curve which represents the ratio full-load power draw of the exhaust fan as a function of the ratio full-load air flow.
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	As designed. The default fan curve shall be selected from Equation (4) and Table 27 for the type of fan specified in the proposed design.
<i>Standard Design</i>	The baseline building fan curve shall be selected from Equation (4) and Table 27 for the type of fan specified in the proposed design.

**Exhaust Fan Power Index**

<i>Applicability</i>	All exhaust systems
<i>Definition</i>	The fan power of the exhaust fan per unit of flow. This building descriptor is applicable only with the power-per-unit-flow method.
<i>Units</i>	

kW/cfm

*Input Restrictions* As designed.*Standard Design* Not applicable

### 5.7.3.5 Garage Exhaust Fan Systems

Garage exhaust fan systems shall be modeled and included as part of regulated building energy use. Garage exhaust fans do not serve conditioned space and are not included as part of the fan power index for the building. These fans shall be modeled as constant volume fans, with the fan power determined by whether or not the fan has CO controls.

#### Garage Exhaust Fan Name

*Applicability* All garage exhaust systems*Definition* A unique descriptor for each garage exhaust fan or fan system. Fans with equivalent efficiency and motor efficiencies may be combined and modeled as one fan.*Units* Text, unique*Input Restrictions* Where applicable, this should match the tags that are used on the plans.*Standard Design* The baseline building will have an exhaust system that corresponds to the proposed design. The name can be identical to that used for the proposed design or some other appropriate name may be used.

#### Garage Exhaust Fan System Modeling Method

*Applicability* All exhaust fan systems*Definition* Software commonly models fans in three ways. See definition for supply system modeling method.*Units* List: power-per-unit-flow, static pressure or brake horsepower*Input Restrictions* Power-per-unit-flow (fixed value)*Standard Design* The baseline building shall use the power-per-unit-flow method.

#### Garage Exhaust Fan Rated Capacity

*Applicability* All exhaust systems*Definition* The rated design air flow rate of the garage exhaust fan system.*Units* cfm*Input Restrictions* As designed*Standard Design* Same as proposed design

#### Garage Exhaust Fan Control Method

*Applicability* All exhaust fan systems*Definition* The control method for the garage exhaust fan. This input determines the fan power for the exhaust fan; no other fan inputs are required.*Units* List: Constant Volume, CO Control*Input Restrictions* For systems with fan capacity below 10,000 cfm, either *Constant Volume* or *CO Control*

	For systems with fan capacity above 10,000 cfm, either <i>Constant Volume</i> or <i>CO Control</i>
	If <i>Constant Volume</i> is selected, proposed fan power is 0.35 W/cfm
	If <i>CO Control</i> is selected, proposed fan power is 0.044 W/cfm
<i>Standard Design</i>	The bhp exhaust fan bhp for the baseline building is calculated from the garage system fan power index (FPI) and the exhaust fan ratio through the following formula:  $\text{FPI} = \text{bhp} \times 746 / \eta_m$ <p>For garage fans with a supply air flowrate below 10,000 cfm, the baseline fan power is 0.35 W/cfm.</p> <p>For garage fans with a design supply air flowrate of 10,000 cfm and above, the baseline fan power is 0.044 W/cfm.</p>

## 5.7.4 Outdoor Air Controls and Economizers

### 5.7.4.1 Outside Air Controls

#### Maximum Outside Air Ratio

<i>Applicability</i>	All systems with modulating outside air dampers
<i>Definition</i>	The descriptor is used to limit the maximum amount of outside air that a system can provide as a percentage of the design supply air. It is used where the installation has a restricted intake capacity.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	One of the following choices:  All other systems: as designed
<i>Standard Design</i>	1.0 for all systems above 54,000 Btu/h cooling capacity and for systems serving laboratory spaces or occupancies; 0.9 for other systems

#### Design Outside Air Flow

<i>Applicability</i>	All systems with outside air dampers
<i>Definition</i>	The rate of outside air that needs to be delivered by the system at design conditions. This input may be derived from the sum of the design outside air flow for each of the zones served by the system.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed, but no lower than the ventilation rate of the standard design.
<i>Standard Design</i>	Minimum ventilation requirements specified by Standard 120(b)2 as the greater of 15 cfm/person and the minimum ventilation rates specified in Appendix 5.4  For systems serving laboratory spaces, the system shall be 100% outside air, with ventilation rates determined by the Authority Having Jurisdiction.  See <i>ventilation control method</i> at the zone level.

#### Outdoor Air Control Method

<i>Applicability</i>	All HVAC systems that deliver outside air to zones
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<i>Definition</i>	<p>The method of determining the amount of outside air that needs to be delivered by the system. Each of the zones served by the system report their outside air requirements on an hourly basis. The options for determining the outside air at the zone level are discussed above. This control method addresses how the system responds to this information on an hourly basis. Options include:</p> <ul style="list-style-type: none"> <li>• <b>Average Flow.</b> The outside air delivered by the system is the sum of the outside air requirement for each zone, without taking into account the position of the VAV damper in each zone. The assumption is that there is mixing between zones through the return air fan.</li> <li>• <b>Critical Zone.</b> The critical zone is the zone with the highest ratio of outside air to supply air. The assumption is that there is no mixing between zones. This method will provide greater outside air than the average flow method because when the critical zone sets the outside air fraction at the system, the other zones are getting greater outside air than required.</li> </ul> <p>The quantity of outside air can be controlled in a number of ways, but a common method is to install a flow station at the outside air supply which modulates the position of the outside air and return dampers to maintain the desired outside air flow. With the average flow, a CO<sub>2</sub> sensor in the return air duct is another way to control the position of the outside air and return dampers.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as proposed design

### 5.7.4.2 Air Side Economizers

#### Economizer Control Type

<i>Applicability</i>	All systems with an air-side economizer
<i>Definition</i>	<p>An air-side economizer increases outside air ventilation during periods when refrigeration loads can be reduced from increased outside air flow. The control types include:</p> <ul style="list-style-type: none"> <li>• <b>No economizer</b></li> <li>• <b>Fixed dry-bulb.</b> The system shifts to 100% outside air and shuts off the cooling when the temperature of the outside air is equal to or lower than the supply air temperature.</li> <li>• <b>Differential dry-bulb.</b> The system shifts to 100% outside air when the temperature of the outside air is lower than the return air temperature but continues to operate the cooling system until the outside air temperature reaches the supply air temperature.</li> <li>• <b>Fixed enthalpy and fixed dry-bulb.</b> The system shifts to 100% outside air and shuts off the cooling when the enthalpy of the outside air is equal to or lower than the supply air enthalpy or the outside air temperature drops below a fixed dry-bulb limit.</li> <li>• <b>Differential enthalpy.</b> The system shifts to 100% outside air when the enthalpy of the outside air is lower than the return air enthalpy but continues to operate the cooling system until the outside air enthalpy reaches the supply air enthalpy.</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	

	As designed
<i>Standard Design</i>	The control should be no economizer when the baseline cooling capacity $\leq 54,000$ Btu/h. <u>Otherwise the baseline building shall assume an integrated differential dry-bulb economizer.</u>  An exception is that economizers shall NOT be modeled for systems serving high-rise residential or hotel/motel guestroom occupancies.

**Economizer Integration Level**

<i>Applicability</i>	Airside economizers
<i>Definition</i>	This input specifies whether or not the economizer is integrated with mechanical cooling. It is up to the modeling software to translate this into software-specific inputs to model this feature. The input could take the following values: <ul style="list-style-type: none"> <li>• Non-integrated. The system runs the economizer as the first stage of cooling. When the economizer is unable to meet the load, the economizer returns the outside air damper to the minimum position and the compressor turns on as the second stage of cooling.</li> <li>• Integrated. The system can operate with the economizer fully open to outside air and mechanical cooling active (compressor running) simultaneously, even on the lowest cooling stage.</li> </ul>
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	List: Non-integrated, Integrated
<i>Standard Design</i>	Integrated for systems above capacity 65,000 Btu/h at ARI conditions

**Economizer High Temperature Lockout**

<i>Applicability</i>	Systems with <i>fixed dry-bulb</i> economizer
<i>Definition</i>	It is the outside air setpoint temperature above which the economizer will return to minimum position.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	For California Compliance, the baseline building shall assume an integrated fixed dry-bulb economizer with the following limits:  Climate Zone 7: dry-bulb high limit of 69°F Climate Zones 6, 8, 9: dry-bulb high limit of 71°F Climate Zones 2, 4, 10: dry-bulb high limit of 73°F Climate Zones 1, 3, 5, 11-16: dry-bulb high limit of 75°F

**Economizer Low Temperature Lockout**

<i>Applicability</i>	Systems with air-side economizers
<i>Definition</i>	A feature that permits the lockout of economizer operation (return to minimum outside air position) when the outside air temperature is below the lockout setpoint.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	

Not used

#### **Economizer High Enthalpy Lockout**

<i>Applicability</i>	Systems with fixed enthalpy or differential enthalpy economizers
<i>Definition</i>	The outside air enthalpy above which the economizer will return to minimum position
<i>Units</i>	Btu/lb
<i>Input Restrictions</i>	As designed. The default is 28 Btu/lb.(High altitude locations may require different setpoints.) The compliance software shall apply a fixed offset and add 2 Btu/lb to the user-entered value.
<i>Standard Design</i>	No lockout limit

## **5.7.5 Cooling Systems**

### **5.7.5.1 General**

This group of building descriptors applies to all cooling systems.

#### **Cooling Source**

<i>Applicability</i>	All systems
<i>Definition</i>	The source of cooling for the system. The choices are: <ul style="list-style-type: none"> <li>• Chilled water</li> <li>• Direct expansion (DX)</li> <li>• Other</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline building cooling source is shown in Table 28. See Table 5 – HVAC System Map for HVAC system mapping.

**Table 28 – Cooling Source for Baseline Building System**

Baseline building System	Cooling Source
System 1 – PTAC	Direct expansion (DX)
System 2 – FPFC	Chilled water
System 3 – PSZ-AC	Direct expansion (DX)
System 5 – Packaged VAV with Reheat	Direct expansion (DX)
System 6 – VAV with Reheat	Chilled water
System 7 – PSZ, Single Zone VAV	Direct expansion (DX)
System 9 – Heating and Ventilation	None
System 10 – CRAH Unit for Data Centers	Chilled water
System 11 – CRAC Unit for Data Centers	Direct expansion (DX)

#### **Total Cooling Capacity**

<i>Applicability</i>	All cooling systems
<i>Definition</i>	The total cooling capacity (both sensible and latent) of a cooling coil or packaged DX

system at ARI conditions. The building descriptors defined in this chapter assume that the fan is modeled separately, including any heat it adds to the air stream. The cooling capacity specified by this building descriptor should not consider the heat of the fan.

*Units*

kBtu/h

*Input Restrictions*

As designed. For packaged equipment that has the fan motor in the air stream such that it adds heat to the cooled air, the software shall adjust the *total cooling capacity* as follows:

(6)

$$Q_{t,adj} = Q_{t,rated} + BHP_{supply} \times 2.545$$

where

$Q_{t,adj}$  The adjusted total cooling capacity of a packaged unit (kBtu/h)

$Q_{t,rated}$  The ARI rated total cooling capacity of a packaged unit (kBtu/h) from manufacturers' literature

$BHP_{supply}$  The supply fan brake horsepower (bhp).

If the number of unmet load hours in the proposed design exceeds 300, the software shall warn the user to resize the equipment.

*Standard Design*

The total cooling capacity of the systems in the baseline building is oversized by 15%.. Sizing calculations shall be based on 0.5% design dry-bulb and mean coincident wet-bulb.

### Sensible Cooling Capacity

*Applicability*

All cooling systems

*Definition*

The sensible cooling capacity of the coil or packaged equipment at ARI conditions. The building descriptors defined in this chapter assume that the fan is modeled separately, including any heat it adds to the air stream. The cooling capacity specified by this building descriptor should not consider the heat of the fan.

Note that the sensible heat ratio (SHR) used by some energy simulation tools can be calculated from the sensible cooling capacity and total cooling capacity:

$$SHR = \text{Sensible Cooling Capacity} / \text{Total Cooling Capacity}$$

*Units*

kBtu/h

*Input Restrictions*

As designed. For packaged equipment that has the fan motor located in the air stream such that it adds heat to the cooled air, the software shall adjust the *sensible cooling capacity* as follows:

(7)

$$Q_{s,adj} = Q_{s,rated} + BHP_{supply} \times 2.545$$

where

$Q_{s,adj}$  The adjusted sensible cooling capacity of a packaged unit (kBtu/h)

$Q_{s,rated}$  The ARI rated sensible cooling capacity of a packaged unit (kBtu/h)

$BHP_{supply}$  The supply fan brake horsepower (bhp).

If the number of unmet load hours in the proposed design exceeds 300, the software shall warn the user to resize the equipment.

*Standard Design* The sensible cooling capacity of the systems serving baseline building is oversized by 15%. Sizing calculations shall be based on 0.5% design dry-bulb and mean coincident wet-bulb.

### Cooling Capacity Adjustment Curves

*Applicability* All cooling systems

*Definition* A curve that represents the available total cooling capacity as a function of cooling coil and/or condenser conditions. The common form of these curves is given as follows:

$$Q_{t,available} = CAP\_FT \times Q_{t,adj} \quad (8)$$

For air cooled direct expansion

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{wb} \times t_{odb} \quad (9)$$

For water cooled direct expansion

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{wt} + e \times t_{wt}^2 + f \times t_{wb} \times t_{wt} \quad (10)$$

For chilled water coils

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{db} + e \times t_{db}^2 + f \times t_{wb} \times t_{db} \quad (11)$$

where

$Q_{t,available}$	Available cooling capacity at specified evaporator and/or condenser conditions (MBH)
$Q_{t,adj}$	Adjusted capacity at ARI conditions (Btu/h) (see Equation (6))
$CAP\_FT$	A multiplier to adjust $Q_{t,adj}$
$t_{wb}$	The entering coil wet-bulb temperature (°F)
$t_{db}$	The entering coil dry-bulb temperature (°F)
$t_{wt}$	The water supply temperature (°F)
$t_{odb}$	The outside-air dry-bulb temperature (°F)

Note: if an air-cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

Software may represent the relationship between cooling capacity and temperature in ways other than the equations given above.

Table 29 –Cooling Capacity Curve Coefficients

Coefficient	Air Cooled Direct Expansion		Water Cooled Direct Expansion		Chilled Water Coils	
	Air-Source (PTAC)	Air-Source (Other DX)	Water-Source (Heat Pump)	Water-Source (Other DX)	Fan-Coil	Other Chilled Water
a	1.1839345	0.8740302	-0.2780377	0.9452633	0.5038866	2.5882585
b	-0.0081087	-0.0011416	0.0248307	-0.0094199	-0.0869176	-0.2305879
c	0.0002110	0.0001711	-0.0000095	0.0002270	0.0016847	0.0038359
d	-0.0061435	-0.0029570	-0.0032731	0.0004805	0.0336304	0.1025812
e	0.0000016	0.0000102	0.0000070	-0.0000045	0.0002478	0.0005984
f	-0.0000030	-0.0000592	-0.0000272	-0.0000599	-0.0010297	-0.0028721

Note: These curves are the DOE-2.1E defaults, except for Water-Source (Other DX), which is taken from the “ECB Compliance Supplement, public review draft prepared by the SSPC 90.1 ECB Panel, Version 1.2, March 1996.

**Units** Data structure

**Input Restrictions** As designed. The equations and coefficients given above are the default.

**Standard Design** Use the default curves or equivalent data for other models.

### Coil Bypass Factor

**Applicability** All DX cooling systems (optional input)

**Definition** The ratio of air that bypasses the cooling coil at design conditions to the total system airflow.

**Units** Ratio

**Input Restrictions** Prescribed values as shown in Table 30.

Table 30 – Default Coil Bypass Factors

System Type	Default Bypass Factor
Packaged Terminal Air-conditioners and Heat Pumps	0.241
Other Packaged Equipment	0.190
Multi-Zone Systems	0.078
All Other	0.037

**Standard Design** Defaults

### Coil Bypass Factor Adjustment Curve

**Applicability** All DX cooling systems (optional input)

**Definition** Adjustments for the amount of coil bypass due to the following factors:

- Coil airflow rate as a percentage of rated system airflow
- Entering air wet-bulb temperature
- Entering air dry-bulb temperature
- Part load ratio

**Units** Data structure

**Input Restrictions** Where applicable, prescribed (fixed) simulation engine defaults based on HVAC

system type. The following default values shall be used for the adjustment curves:

(12)

$$CBF_{adj} = CBF_{rated} \times COIL - BF - FFLOW \times COIL - BF - FT \times COIL - BF - FPLR$$

(13)

$$COIL - BF - FFLOW = a + b \times CFMR + c \times CFMR^2 + d \times CFMR^3$$

(14)

$$COIL - BF - FT = a + b \times T_{wb} + c \times T_{wb}^2 + d \times T_{db} + e \times T_{db}^2 + f \times T_{wb} \times T_{db}$$

(15)

$$COIL - BF - FPLR = a + b \times PLR$$

where

$CBF_{rated}$	The coil bypass factor at ARI rating conditions
$CBF_{adj}$	The coil bypass factor adjusted for airflow and coil conditions
CFMR	The ratio of airflow to design airflow
COIL-BF-FFLOW	A multiplier on the rated coil bypass factor to account for variation in air flow across the coil (take coefficients from Table 31)
COIL-BF-FT	A multiplier on the rated coil bypass factor to account for a variation in coil entering conditions (take coefficients from Table 32)
COIL-BF-FPLR	A multiplier on the rated coil bypass factor to account for the part load ratio (take coefficients from Table 33)
$T_{wb}$	The entering coil wet-bulb temperature (°F)
$T_{db}$	The entering coil dry-bulb temperature (°F)
PLR	Part load ratio

And the coefficients are listed in the tables below.

**Table 31 – Coil Bypass Factor Airflow Adjustment Factor**

Coefficient	COIL-BF-FFLOW (PTAC)	COIL-BF-FFLOW (HP)	COIL-BF-FFLOW (PSZ/other)
a	-2.277	-0.8281602	-0.2542341
b	5.21140	14.3179150	1.2182558
c	-1.93440	-21.8894405	0.0359784
d		9.3996897	

**Table 32 – Coil Bypass Factor Temperature Adjustment Factor**

Coefficient	COIL-BF-FT (PTAC)	COIL-BF-FT (HP)	COIL-BF-FT (PSZ, other)
a	-1.5713691	-29.9391098	1.0660053
b	0.0469633	0.8753455	-0.0005170
c	0.0003125	-0.0057055	0.0000567
d	-0.0065347	0.1614450	-0.0129181
e	0.0001105	0.0002907	-0.0000017
f	-0.0003719	-0.0031523	0.0001503

**Table 33 – Coil Bypass Factor Part Load Adjustment Factor**

Coefficient	COIL-BF-FPLR (All Systems)
a	0.00
b	1.00

*Standard Design*      Use defaults as described above.

### 5.7.5.2 Direct Expansion

#### Direct Expansion Cooling Efficiency

*Applicability*      Packaged DX equipment

*Definition*      The cooling efficiency of a direct expansion (DX) cooling system at ARI rated conditions as a ratio of output over input in Btu/h per W, excluding fan energy. The abbreviation used for this full-load efficiency is EER.

For all unitary and applied equipment where the fan energy is part of the equipment efficiency rating, the EER shall be adjusted as follows:

(16)

$$EER_{adj} = \frac{Q_{t,rated} + BHP_{supply} \times 2.545}{\frac{Q_{t,rated}}{EER} - BHP_{supply} \times 0.7457}$$

where

$EER_{adj}$       The adjusted *Energy Efficiency Ratio* for simulation purposes  
 $EER$       The rated *Energy Efficiency Ratio*  
 $Q_{t,rated}$       The ARI rated total cooling capacity of a packaged unit (kBtu/h)  
 $BHP_{supply}$       The supply fan brake horsepower (bhp) shall be taken from manufacturers' literature when available, otherwise use Equation (5).

<i>Units</i>	Btu/h-W
<i>Input Restrictions</i>	As designed. When possible, specify the SEER and EER for packaged equipment with cooling capacity less than 65,000 Btu/h from manufacturer's literature. For equipment with capacity above 65,000 Btu/h, specify EER.  When EER is not available for packaged equipment with SEER ratings (ARI cooling capacity of 65,000 Btu/h or smaller), it shall be calculated as follows:
	(17)
	$\text{EER} = 10 - (11.5 - \text{SEER}) \times 0.83 \text{ when } \text{SEER} \leq 11.5$ $= 10 \text{ when } \text{SEER} \geq 11.5$
	Evaporative cooling systems that pass the requirements of the Western Cooling Challenge may be modeled with an EER as if the equipment were packaged unitary equipment. The EER used is provided from the testing results, and may exceed 30 for some systems.
<i>Standard Design</i>	Use the minimum cooling efficiency (EER) from tables in Tables 110.2-A, 110.2-B and 110.2-E in Section 110.2 of the Standard.

### Seasonal Energy Efficiency Ratio

<i>Applicability</i>	Packaged DX equipment with ARI cooling capacity of 65,000 Btu/h or smaller
<i>Definition</i>	The seasonal cooling efficiency of a direct expansion (DX) cooling system at ARI rated conditions as a ratio of output over input in Btu/h per W, excluding fan energy. The software must accommodate user input in terms of either the <i>Energy Efficiency Ratio</i> (EER) or the <i>Seasonal Energy Efficiency Ratio</i> (SEER). For equipment with SEER ratings, EER shall be taken from manufacturers' data when it is available.
<i>Units</i>	Btu/h-W
<i>Input Restrictions</i>	As designed. This input is required for small DX systems. The Direct Expansion Cooling Efficiency input is optional for these systems.
<i>Standard Design</i>	Use the minimum SEER from the 2009 Appliance Efficiency Standards.

### Direct Expansion Cooling Efficiency Temperature Adjustment Curve

<i>Applicability</i>	Packaged DX equipment
<i>Definition</i>	A curve that varies the cooling efficiency of a direct expansion (DX) coil as a function of evaporator conditions, condenser conditions, and for small packaged equipment, part-load ratio.
	(18)

For air-cooled DX systems:

$$\text{EIR}_{FT} = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{wb} \times t_{odb} \quad (19)$$

For water-cooled DX systems:

$$\text{EIR}_{FT} = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{wt} + e \times t_{wt}^2 + f \times t_{wb} \times t_{wt}$$

(20)

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

where

$PLR$	Part load ratio based on available capacity (not rated capacity)
$EIR\_FT$	A multiplier on the EIR to account for the wet-bulb temperature entering the coil and the outdoor dry-bulb temperature
$Q_{operating}$	Present load on heat pump (Btu/h)
$Q_{available}$	Heat pump available capacity at present evaporator and condenser conditions (in Btu/h).
$t_{wb}$	The entering coil wet-bulb temperature (°F)
$t_{wt}$	The water supply temperature (°F)
$t_{odb}$	The outside-air dry-bulb temperature (°F)
$P_{rated}$	Rated power draw at ARI conditions (kW)
$P_{operating}$	Power draw at specified operating conditions (kW)

Note: if an air-cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

Table 34 – Cooling System Coefficients for EIR-FT

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (PSZ with Cool Cap ≤65,000 Btu/h)	Air-Source (Other)
a	2.0280385	-1.8394760	-0.6550461	n/a (see Standard Design)	-1.0639310
b	-0.0423091	0.0751363	0.0388910	n/a	0.0306584
c	0.0003054	-0.0005686	-0.0001925	n/a	-0.0001269
d	0.0149672	0.0047090	0.0013046	n/a	0.0154213
e	0.0000244	0.0000901	0.0001352	n/a	0.0000497
f	-0.0001640	-0.0001218	-0.0002247	n/a	-0.0002096

#### Units

Data structure

#### Input Restrictions

For equipment larger than 135,000 Btu/h, the user may enter data on equipment performance as described below. In this case, the ACM compliance software shall use the algorithms described below to determine the temperature dependent performance curves for the proposed design equipment. If the user chooses not to enter data on temperature dependent performance, then the defaults shall be used.

For equipment with a capacity less than or equal to 135,000 Btu/h, but larger than 65,000 Btu/h, the user may not enter data on the temperature dependent equipment performance. However, the ACM compliance software vendor may work with manufacturers to collect such data and build this data into the ACM compliance software. The user may either select equipment for which the ACM compliance software vendor has collected or use the defaults.

**NOTE: SECTION 2.5.2.6 OF THE NACM HAS SPECIFIC PROCEDURES FOR ENTERING IN USER DATA (FOR INSTANCE, THE NORMALIZED EIR MUST BE MODIFIED BY A  $F_{FDD}$  AND  $F_{AIR}$  ADJUSTMENT FACTORS BASED ON THE PRESENCE OF FDD AND AIRFLOW TESTING.)**

*Standard Design* For all systems except packaged DX units with cooling capacity  $\leq 65,000$  Btu/h, use default curves from Table 55. For packaged DX units with cooling capacity less than or equal to 65,000 Btu/h that have SEER ratings, the user inputs EER and SEER, and the software generates the equipment performance curve based on the algorithm below.

**NOTE: TITLE 24-2008 HAS A PROCEDURE FOR DEVELOPING A CURVE-FIT FOR THE EIR-FT BASED ON USER INPUTS OF SEER AND EER. THIS CURVE INCORPORATES BOTH TEMPERATURE EFFECTS AND PART-LOAD EFFECTS. SOFTWARE MUST BE ABLE TO GENERATE A BI-QUADRATIC CURVE FROM INPUT DATA TO USE THIS APPROACH. SEE 2.5.2.7 – THIS ONLY APPLIES TO EQUIPMENT WITH SEER RATINGS.**

This curve explains how the efficiency of the cooling equipment varies with the ODB and the EWB. This curve is derived from entered or default values of SEER and EER, using the procedures below.

The curve is defined as a bi-quadratic with the following coefficients.

COOL-EIR- FT = CURVE-FIT  
 TYPE = BI-QUADRATIC  
 DATA = (67, 95, 1.0, \$ARI Test Conditions  
 57, 82, NEIR<sub>57,82</sub>  
 57, 95, NEIR<sub>57,95</sub>,  
 57, 110, NEIR<sub>57,110</sub>,  
 67, 82, NEIR<sub>67,82</sub>,  
 67, 110, NEIR<sub>67,110</sub>,  
 77, 82, NEIR<sub>77,82</sub>,  
 77, 95, NEIR<sub>77,95</sub>,  
 77, 110, NEIR<sub>77,110</sub>)  
 OUTPUT-MIN = NEIR<sub>67,82</sub>

NEIR<sub>WB,ODB</sub> represents the normalized energy input ratio (EIR) for various entering wet-bulb (EWB) and outside dry-bulb (ODB) temperatures. The value represents the EIR at the specified EWB and ODB conditions to the EIR at standard ARI conditions of 67° °F wet-bulb and 95° °F dry-bulb. The COOL-EIR-FT curve is normalized at ARI conditions of 67° °F entering wet-bulb and 95° °F outside dry-bulb so NEIR<sub>67,95</sub> is one or unity, by definition. For other EWB and ODB conditions, values of NEIR are calculated with Equation N2-21.

Equation N2-21

$$NEIR_{EWB,ODB} = \frac{EIR_{EWB,ODB}}{EIR_{67,95}}$$

The energy input ratio (EIR) is the unitless ratio of energy input to cooling capacity. EIR includes the compressor and condenser fan, but not the supply fan. If the energy efficiency ratio EER<sub>nf</sub> (EER excluding the fan energy) is known for a given set of EWB and ODB conditions, the EIR for these same conditions is given by Equation N2-22 below. The units of EER are (Btu/h)/W.

Equation N2-22

$$EIR_{EWB,ODB} = \frac{3.413}{EER_{nf,EWB,ODB}}$$

If the EER (including fan energy) is known for a given set of EWB and ODB conditions, then the EER<sub>nf</sub> (no fan) can be calculated from Equation N2-23 below.

$$\begin{aligned} EER_{nf,EWB,ODB} = & 1.0452 \times EER_{EWB,ODB} \\ & + 0.0115 \times EER_{EWB,ODB}^2 \\ & + 0.000251 \times EER_{EWB,ODB}^3 \times F_{FDD} \times F_{AIR} \end{aligned}$$

Equation N2-23

$$\text{Equation N2-24} \quad \text{EER}_{\text{nf}_{\text{EWB,ODB}}} = (1.0452 \times \text{EER}_{\text{EWB,ODB}} + 0.0115 \times \text{EER}_{\text{EWB,ODB}}^2 + 0.000251 \times \text{EER}_{\text{EWB,ODB}}^3) \times F_{\text{FDD}} \times F_{\text{AIR}}$$

The EER for different EWB and ODB conditions. These are given by the following equations.

$$\text{Equation N2-25} \quad \text{EER}_{67,82} = \text{SEER}$$

$$\begin{aligned} \text{Equation N2-26} \quad \text{EER}_{67,95} &= \text{From Manufacturers Data} \quad [\text{when available}] \\ &= 10 - (11.5 - \text{SEER}) \times 0.83 \quad [\text{default for SEER} < 11.5] \\ &= 10 \quad [\text{default for SEER} \geq 11.5] \end{aligned}$$

$$\text{Equation N2-27} \quad \text{EER}_{67,110} = \text{EER}_{67,95} - 1.8$$

$$\text{Equation N2-28} \quad \text{EER}_{57,ODB} = 0.877 \times \text{EER}_{67,ODB}$$

$$\text{Equation N2-29} \quad \text{EER}_{77,ODB} = 1.11 \times \text{EER}_{67,ODB}$$

$F_{\text{TXV}}$  Refrigerant charge factor, default = 0.9. For systems with a verified TXV or verified refrigerant charge, the factor shall be 0.96.

$F_{\text{AIR}}$  Airflow adjustment factor. Default cooling air flow shall be assumed in calculations for any system in which the air flow has not been tested, certified and verified. For ACM compliance software energy calculations the  $F_{\text{air}}$  multiplier shall be set to 0.925 for systems with default cooling air flow. For systems with air flow verified,  $F_{\text{air}}$  shall be 1.00.

$\text{EER}_{\text{nf}}$  Energy Efficiency Ratio at ARI conditions without distribution fan consumption, but adjusted for refrigerant charge and airflow.

#### Direct Expansion Part-Load Efficiency Adjustment Curve

**Applicability** Packaged systems with direct expansion (DX) cooling

**Definition** A normalized performance adjustment curve to the rated efficiency (Energy Input Ratio) that describes how the efficiency varies at part-load conditions. At a value of 1 (full load), the normalized efficiency is 1 (same as part-load conditions).

The default curves are given as follows as adjustments to the energy input ratio (EIR)<sup>8</sup>:

<sup>8</sup> The EIR is the ratio of energy used by the system to cooling capacity in the same units. It is the reciprocal of the coefficient of performance (COP). EnergyPlus uses a part-load factor correlation for PLF as a function of PLR. The EnergyPlus PLF is related to the DOE-2 EIR(PLR) by the following:  $\text{EIR-FPLR} = \text{PLR} / \text{PLF}$ .

(30)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{wb}, t_{odb/wt})}$$

(31)

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

$$PLF\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

This curve may take the form of a part-load factor (PLF) or EIR-FLPR, which is the fraction of time the unit must run to meet the part-load for that hour. For example, at 40% of full load, the equipment might need to run 50% of the hour (for cycling losses).

Note that for small packaged equipment with SEER ratings (<65,000 Btu/h), the part-load efficiency curve is set to no degradation, since the part-load degradation is built-into the *Direct Expansion Cooling Efficiency Temperature Adjustment Curve*.

Default curves are provided for the different major classes of equipment.

**Units**

Coefficients (three for a quadratic, or up to four for a cubic)

**Input Restrictions**

The coefficients should sum to 1 (within a small tolerance). This corresponds to a curve output of 1 for an input of 1.

**Standard Design**

The baseline part-load efficiency adjustment curves are shown in the tables below.

**Table 35 – Cooling System Coefficients for EIR-FPLR**

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (PSZ with Cap<65,000 Btu/h)	Air-Source (Other)
a	0.1250000	0.2012301	0.1250000	0	0.2012301
b	0.8750000	-0.0312175	0.8750000	1	-0.0312175
c	0.0000000	1.9504979	0.0000000	0	1.9504979
d	0.0000000	-1.1205105	0.0000000	0	-1.1205105

**Table 36 – Cooling System Coefficients for Part-Load Factor (PLF) Correlation (EnergyPlus)**

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (PSZ with Cap<65,000 Btu/h)	Air-Source (Other)
a	0.85	0	0.85	1	0
b	0.15	5.1091	0.15	0	5.1091
c	0	-8.5515	0	0	-8.5515
d	0	4.4744	0	0	4.4744

### Refrigerant Charge Factor

**Applicability**

Packaged systems

**Definition**

An adjustment factor to the cooling efficiency and for heat pumps, heating efficiency, curves for packaged equipment. The refrigerant charge factor is a divisor in the term

for cooling efficiency (energy input ratio) or multiplier in the adjustment of energy efficiency ratio that assumes slightly degraded performance if refrigerant charge is not verified through acceptance test procedures in the Nonresidential Appendix of the Standards.

<i>Units</i>	Ratio
<i>Input Restrictions</i>	Refrigerant charge factor, default = 0.9. For systems with a verified TXV or verified refrigerant charge, the factor shall be 0.96. For evaporative cooling systems that meet the Western Cooling Challenge requirements, the refrigerant charge factor shall be 0.96.
<i>Standard Design</i> greater.	The default shall be 0.96 for all systems with ARI cooling capacity of 54,000 Btu/h or greater.

#### **Airflow Adjustment Factor**

<i>Applicability</i>	Packaged systems
<i>Definition</i>	An adjustment factor to the cooling efficiency and for heat pumps, heating efficiency, curves for packaged equipment. The airflow adjustment factor is a divisor in the term for cooling efficiency (energy input ratio) or multiplier in the term for energy efficiency ratio that assumes slightly degraded performance if airflow is not verified through acceptance test procedures in the Nonresidential Appendix of the Standards.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	For ACM compliance software energy calculations the airflow adjustment factor ( $F_{air}$ ) multiplier shall be set to 0.925 for systems with default cooling air flow. For systems with air flow verified meeting the requirements of Reference Appendix NA9, $F_{air}$ shall be 1.00.  For evaporative cooling systems that meet the Western Cooling Challenge requirements, the airflow adjustment factor shall be 1.00.
<i>Standard Design</i>	The default shall be 1.00 for all systems with ARI cooling capacity of 54,000 Btu/h or greater.

**NOTE: THE FOLLOWING BUILDING DESCRIPTORS APPLY TO THE SINGLE-ZONE VAV SYSTEM, WHICH IS THE BASELINE FOR APPLICABLE BUILDINGS WITH ZONE COOLING LOADS OF 110,000 BTU/H OR GREATER, AND THE REQUIREMENT SCOPE EXPANDS TO UNITS WITH CAPACITY OF 75,000 BTU/H OR GREATER IN 2014 AND 65,000 BTU/H OR GREATER IN 2016.**

**TABLE 140.4-D EFFECTIVE DATES FOR FAN CONTROL SYSTEMS**

Cooling System Type	Fan Motor Size	Cooling Capacity	Effective Date
DX Cooling	any	$\geq 110,000$ Btu/hr	1/1/2012
		$\geq 75,000$ Btu/hr	1/1/2014
		$\geq 65,000$ Btu/hr	1/1/2016
Chilled Water and Evaporative	$\geq 5$ HP	any	1/1/2010
	$\geq 1$ HP	any	1/1/2014
	$\geq 1/4$ HP	any	1/1/2016

**Number of Cooling Stages**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	This applies to the baseline HVAC system Single Zone VAV. This system is a packaged unit with multiple compressors and a two-speed or variable-speed fan. Systems with unequally sized compressors may have additional cooling stages.
<i>Units</i>	None (Integer)
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be 2 for the Single Zone VAV baseline.

**Total Cooling Capacity by Stage**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	This provides the total cooling capacity of each cooling stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated cooling capacity for the unit. For example, if the stage cooling capacity is 4 tons (48,000 Btu/h) and the total cooling capacity is 8 tons (96,000 Btu/h), the capacity is expressed as "0.50" for that stage.
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be (0.50, 1) for the Single Zone VAV baseline.

**Sensible Cooling Capacity by Stage**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	This provides the sensible cooling capacity of each cooling stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated cooling capacity for the unit. For example, if the stage sensible cooling capacity is 3 tons (36,000 Btu/h) and the total cooling capacity is 9 tons (108,000 Btu/h), the capacity is expressed as "0.33" for that stage.
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be (0.50, 1) for the Single Zone VAV baseline.

**Supply Air Temperature Reset by Stage**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	<p>This provides the cooling supply air temperature setpoint deviation from the cooling design supply air temperature, specified in the building descriptor <i>Cooling Supply Air Temperature</i>.</p> <p>The temperature reset is expressed as an array, with each entry a deviation from the design supply air temperature. For example, an entry of "5" for a stage would indicate a 5°F reset (for example, 60°F from 55°F).</p>
<i>Units</i>	Array of temperature differences, in degrees F
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be (5,0) for the Single Zone VAV baseline.

**Number of Heating Stages**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	The number of heating stages provided by the system. Multiple stages could be provided via a heat pump or via a multiple-stage gas furnace.
<i>Units</i>	Integer
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be 2 for the Single Zone VAV baseline.

**Heating Capacity by Stage**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	This provides the total heating capacity of each heating stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated cooling capacity for the unit. For example, if the stage heating capacity is 48,000 Btu/h and the heating capacity is 96,000 Btu/h, the capacity is expressed as "0.50" for that stage.
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be (0.50, 1) for the Single Zone VAV baseline.

**Heating Supply Air Temperature by Stage**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages
<i>Definition</i>	This provides the heating supply air temperature setpoint deviation from the design heating supply air temperature, specified in the building descriptor <i>Cooling Supply Air Temperature</i> .  The temperature reset is expressed as an array, with each entry a deviation from the design supply air temperature. For example, an entry of "10" for a stage would indicate a 10°F reset (for example, 95°F from 105°F).
<i>Units</i>	Array of temperature differences, in degrees F
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be -10F for the first cooling stage and 0 for the second (high) cooling stage.

**Supply Fan Low Speed Ratio**

<i>Applicability</i>	Single Zone VAV Systems and DX systems with multiple stages and two-speed fans
<i>Definition</i>	This specifies the low fan speed setting on a Single Zone VAV system or DX system with multiple cooling stages.
<i>Units</i>	None (fraction)
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be 0.66 for the Single Zone VAV baseline.

**Supply Fan Low Power Ratio**

<i>Applicability</i>	
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	Single Zone VAV Systems and DX systems with multiple stages and two-speed fans
<i>Definition</i>	This specifies the fraction of full load fan power corresponding to low fan speed operation on a Single Zone VAV system or DX system with multiple cooling stages.
<i>Units</i>	None (fraction)
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	The default shall be 0.40 for the Single Zone VAV baseline.

**NOTE: THE FOLLOWING FOUR BUILDING DESCRIPTORS REPLACE THE PROCEDURE FROM THE 2008 NONRESIDENTIAL ACM APPENDIX D FOR DISTRIBUTION LOSSES FOR DUCTWORK IN UNCONDITIONED SPACES.**

#### **Duct Leakage Rate**

<i>Applicability</i>	Packaged single-zone systems serving spaces less than 5,000 ft <sup>2</sup> with ducts in unconditioned spaces
<i>Definition</i>	The duct air leakage rate from the supply and return duct of a packaged single zone system with ducts in unconditioned spaces.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	The input may contain one of the following three values:

*Table 37 – Duct Leakage Factors*

	as = ar =
Untested duct systems	0.82
Sealed and tested duct systems in existing buildings, System tested after HVAC equipment and/or duct installation	0.915
Sealed and tested new duct systems. System tested after HVAC system installation	0.96

<i>Standard Design</i>	The baseline value shall be 0.96, except: for systems that serve residential occupancies including hotel/motel guest rooms, the baseline value shall be the same as proposed.
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#### **Duct Surface Area**

<i>Applicability</i>	Packaged single-zone systems serving non-residential spaces less than 5,000 ft <sup>2</sup> with ducts in unconditioned spaces
<i>Definition</i>	The duct surface area used for duct heat transfer calculations.
<i>Units</i>	ft <sup>2</sup>
<i>Input Restrictions</i>	Any positive number

<i>Standard Design</i>	For systems serving nonresidential occupancies, the default duct surface area shall be:
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The default duct surface area for supply and return shall be calculated as follows:

For supplies:

Equation ND1

$$A_{s,\text{total}} = K_s A_{\text{floor}}$$

Where  $K_s$  (supply duct surface area coefficient) shall be 0.25 for systems serving the top story only, 0.125 for systems serving the top story plus one other, and 0.08 for systems serving three or more stories.

For returns:

Equation ND2

$$A_{r,\text{total}} = K_r A_{\text{floor}}$$

Where  $K_r$  (return duct surface area coefficient) shall be 0.15 for systems serving the top story only, 0.125 for systems serving the top story plus one other, and 0.08 for systems serving three or more stories.

For systems serving residential occupancies, including hotel/motel guestrooms, the baseline shall be same as proposed.

#### **Duct Surface Area Outdoors**

<i>Applicability</i>	Packaged single-zone systems serving spaces less than 5,000 ft <sup>2</sup> with ducts in unconditioned spaces
<i>Definition</i>	The duct surface area for the portion of ductwork located outdoors. The remainder of the supply ductwork for applicable systems (See Standard 140.4(k)) is assumed to be in unconditioned space between the ceiling and roof.
<i>Units</i>	ft <sup>2</sup>
<i>Input Restrictions</i>	Any positive number

*Standard Design* For systems serving nonresidential spaces, the default duct surface area shall be:

If ducts are located outdoors, the outdoor duct surface area shall be calculated from the duct layout on the plans using measured duct lengths and nominal inside diameters (for round ducts) or inside perimeters (for rectangular ducts) of each outdoor duct run in the building that is within the scope of the calculation procedure. When using the default duct area, outdoor supply duct surface area shall be less than or equal to the default supply duct surface area; outdoor return duct surface area shall be less than or equal to the default return duct surface area.

The surface area of ducts located in the buffer space between ceilings and roofs shall be calculated from:

Equation ND-3

$$A_{s,\text{buffer}} = A_{s,\text{total}} - A_{s,\text{outdoors}}$$

Equation ND4

$$A_{r,\text{buffer}} = A_{r,\text{total}} - A_{r,\text{outdoors}}$$

For systems serving residential spaces including hotel/motel guestrooms, the baseline shall be the same as the proposed.

#### **Duct Insulation Level**

<i>Applicability</i>	Packaged single-zone systems serving spaces less than 5,000 ft <sup>2</sup> with ducts in unconditioned spaces
<i>Definition</i>	The duct insulation R-value for supply and return ductwork for applicable systems
<i>Units</i>	h-ft <sup>2</sup> -F / Btu

<i>Input Restrictions</i>	Any positive number
<i>Standard Design</i>	Nonresidential buildings: R-8 is the baseline insulation level for ductwork in both new construction and alterations of existing buildings  Residential Buildings (including hotel/motel guestrooms): same as proposed

**Minimum Unloading Ratio**

<i>Applicability</i>	Packaged systems which use hot-gas bypass during low load conditions
<i>Definition</i>	The upper end of the hot-gas bypass operating range. This is the percentage of peak cooling capacity below which hot-gas bypass will operate.  The actual unloading ratio shall be set to 50% of the user-entered minimum unloading ratio, with hot-gas-bypass operating below this level.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed. The user must enter this descriptor for each DX cooling system. If hot-gas bypass is not employed, a value of 0 may be entered. A maximum of 0.35 is allowed for units with a peak cooling capacity greater than or equal to 65 kBtu/h and less than 240 kBtu/h (20 tons), and a maximum value of 0.25 is allowed for units with a peak cooling capacity greater than 240 kBtu/h.
<i>Standard Design</i>	Not applicable

**Minimum HGB Ratio**

<i>Applicability</i>	Packaged systems which use hot-gas bypass during low load conditions
<i>Definition</i>	The lower end of the hot-gas bypass operating range. The percentage of peak cooling capacity below which hot-gas bypass will no longer operate (i.e. the compressor will cycle).
<i>Units</i>	Ratio
<i>Input Restrictions</i>	0
<i>Standard Design</i>	0

**Condenser Type**

<i>Applicability:</i>	All direct expansion systems including heat pumps
<i>Definition</i>	The type of condenser for a direct expansion (DX) cooling system. The choices are: <ul style="list-style-type: none"> <li>• Air-Cooled</li> <li>• Water-Cooled</li> <li>• Air-Cooled with Evaporative Pre-cooler</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Based on the prescribed system type. Refer to the HVAC System Map in <b>Error! Reference source not found.</b>

**Table 38 – Baseline Building Condenser Type**

Baseline building System	Condenser Type
System 1 – PTAC	Air-cooled
System 2 – FPFC	Water-cooled
System 3 – PSZ-AC	Air-cooled
System 5 – Packaged VAV with Reheat	Air-cooled
System 6 – VAV with Reheat	Water-Cooled
System 7 – Single Zone VAV	N/A
System 9 – Heating and Ventilation	N/A
System 10 – CRAH Unit	Water-Cooled
System 11 – CRAC Unit	N/A

**Condenser Flow Type**

<i>Applicability:</i>	All direct expansion systems including heat pumps
<i>Definition</i>	Describes water flow control for a water-cooled condenser. The choices are: <ul style="list-style-type: none"> <li>• Fixed Flow</li> <li>• Two-position</li> <li>• Variable Flow</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	Default to fixed flow. If the variable-flow is selected, the software must indicate that supporting documentation is required on the output forms.
<i>Standard Design</i>	Always fixed flow

**5.7.5.3 Evaporative Cooler**

This is equipment that pre-cools the outside air that is brought into the building. It may be used with any type of cooling system that brings in outside air. This equipment is not applicable for the baseline building.

**Evaporative Cooling Type**

<i>Applicability</i>	Systems with evaporative pre-cooling
<i>Definition</i>	<p>The type of evaporative pre-cooler, including:</p> <ul style="list-style-type: none"> <li>• None</li> <li>• Non-Integrated Indirect</li> <li>• Non-Integrated Direct/Indirect</li> <li>• Integrated Indirect</li> <li>• Integrated Direct/Indirect</li> <li>• Western Cooling Challenge (high efficiency)</li> </ul> <p>An integrated pre-cooler can operate together with the compression or CHW cooling. A non-integrated pre-cooler will shut down the evaporative cooling whenever it is unable to provide 100% of the cooling required.</p> <p>In all cases, the evaporative pre-cooler must be modeled with 100% of the outside air routed through the pre-cooler.</p>

The Western Cooling Challenge is a special case of evaporative cooling system that meets the performance and water use requirements defined by the challenge, sponsored by the Western Cooling Efficiency Center. Systems that pass this certification may be modeled like a DX unitary system, with an EER as specified by the results of the test. Special documentation requirements may apply.

<i>Units</i>	None
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### **Direct Stage Effectiveness**

<i>Applicability</i>	Systems with evaporative pre-cooling
<i>Definition</i>	The effectiveness of the direct stage of an evaporative cooling system. Effectiveness is defined as follows:

(32)

$$DirectEFF = \frac{T_{db} - T_{direct}}{T_{db} - T_{wb}}$$

where

DirectEFF	The direct stage effectiveness
$T_{db}$	The entering air dry-bulb temperature
$T_{wb}$	The entering air wet-bulb temperature
$T_{direct}$	The direct stage leaving dry-bulb temperature

<i>Units</i>	Numeric (0 <= eff <=1)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### **Indirect Stage Effectiveness**

<i>Applicability</i>	Systems with evaporative pre-cooling
<i>Definition</i>	The effectiveness of the indirect stage of an evaporative cooling system. Effectiveness is defined as follows:

(33)

$$IndEFF = \frac{T_{db} - T_{ind}}{T_{db} - T_{wb}}$$

where

IndEFF	The indirect stage effectiveness
$T_{db}$	The entering air dry-bulb temperature of the supply air
$T_{wb}$	The entering air wet-bulb temperature of the "scavenger air"
$T_{ind}$	The supply air leaving dry-bulb temperature

<i>Units</i>	Numeric (0 <= eff <=1)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Evaporative Cooling Performance Curves**

**Applicability** Systems with evaporative cooling

**Definition** A curve that varies the evaporative cooling effectiveness as a function of primary air stream airflow. The default curves are given as follows:

(34)

$$PLR = \frac{CFM_{operating}}{CFM_{design}}$$

$$EFF\_FFLOW = a + b \times PLR + c \times PLR^2$$

where

**PLR** Part load ratio of airflow based on design airflow

**EFF-FFLOW** A multiplier on the evaporative cooler effectiveness to account for variations in part load

**$CFM_{operating}$**  Operating primary air stream airflow (cfm)

**$CFM_{design}$**  Design primary air stream airflow (cfm)

**Table 39 – Part Load Curve Coefficients – Evaporative Cooler Effectiveness**

Coefficient	Direct	Indirect
a	1.1833000	1.0970000
b	-0.2575300	-0.1650600
c	0.0742450	0.0680690

**Units** Data structure

**Input Restrictions** User may input curves or use default curves. If defaults are overridden, the software must indicate that supporting documentation is required on the output forms.

**Standard Design** Not used.

**Auxiliary Evaporative Cooling Power**

**Applicability** Systems with evaporative cooling

**Definition** The auxiliary energy of the indirect evaporative cooler fan, and the pumps for both direct and indirect stages

**Units** - Watts

**Input Restrictions** As designed

**Standard Design** Not applicable

**Evaporative Cooling Scavenger Air Source**

**Applicability** Systems with evaporative cooling

**Definition** The source of scavenger air for an indirect section of an evaporative cooler. Options include:

- Return Air
- Outside Air

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### 5.7.5.4 Evaporative Condenser

##### Evaporative Condenser Power

<i>Applicability</i>	Direct expansion systems with an evaporatively cooled condenser
<i>Definition</i>	The power of the evaporative precooling unit. This includes any pump(s) and/or fans that are part of the precooling unit.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

##### Evaporative Condenser Effectiveness

<i>Applicability</i>	Direct expansion systems with an evaporatively cooled condenser
<i>Definition</i>	The effectiveness of the evaporative precooling unit for a condenser. Effectiveness is defined as follows:

(35)

$$DirectEFF = \frac{T_{db} - T_{direct}}{T_{db} - T_{wb}}$$

where

DirectEFF	The direct stage effectiveness
T <sub>db</sub>	The outside air dry-bulb temperature
T <sub>wb</sub>	The outside air wet-bulb temperature
T <sub>direct</sub>	The direct stage leaving dry-bulb temperature (at the condenser inlet)

<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

##### Evaporative Condenser Operation Range

<i>Applicability</i>	Direct expansion systems with an evaporatively cooled condenser.				
<i>Definition</i>	The temperature range within which the evaporative condenser operates. Two values are provided: <table> <tr> <td>T<sub>maximum</sub></td><td>The threshold outside air dry-bulb temperature below which evaporative condenser operates.</td></tr> <tr> <td>T<sub>minimum</sub></td><td>The threshold outside air dry-bulb temperature above which evaporative condenser operates.</td></tr> </table>	T <sub>maximum</sub>	The threshold outside air dry-bulb temperature below which evaporative condenser operates.	T <sub>minimum</sub>	The threshold outside air dry-bulb temperature above which evaporative condenser operates.
T <sub>maximum</sub>	The threshold outside air dry-bulb temperature below which evaporative condenser operates.				
T <sub>minimum</sub>	The threshold outside air dry-bulb temperature above which evaporative condenser operates.				
<i>Units</i>	Degrees Fahrenheit (°F)				
<i>Input Restrictions</i>					

	As designed
<i>Standard Design</i>	Not applicable

### 5.7.5.5 Radiant Cooling

This section describes a floor-based radiant cooling system and the inputs required for Title 24 compliance evaluation.

#### Hydronic Tubing Length

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The length of the hydronic tubing in the slab
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Hydronic Tubing Inside Diameter

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The inside diameter of the hydronic tubing in the slab
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed, between a minimum of ½" and a maximum of ¾"
<i>Standard Design</i>	Not applicable

#### Temperature Control Type

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at Mean Air Temperature for compliance calculations
<i>Standard Design</i>	Not applicable

#### Rated Flow Rate

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at Mean Air Temperature for compliance calculations
<i>Standard Design</i>	Not applicable

#### Cooling Control Temperature

<i>Applicability</i>	Variable Flow Systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean

	radiant temperature, ODB, OWB
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at Mean Air Temperature for compliance calculations
<i>Standard Design</i>	Not applicable

**Condensation Control Type**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at Mean Air Temperature for compliance calculations
<i>Standard Design</i>	Not applicable

**Condensation Control Dewpoint Offset**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature difference above dewpoint that is the minimum cold water supply temperature
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at 2°F above dewpoint
<i>Standard Design</i>	Not applicable

**Rated Pump Power Consumption**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The rated pump power at design conditions
<i>Units</i>	Watts
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	Not applicable

**Motor Efficiency**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The pump motor efficiency
<i>Units</i>	Decimal fraction
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	Default motor efficiency from Table N2-20 ( <i>Table numbering may change</i> ) based on motor nameplate hp

**Fraction of Motor Heat to Fluid**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	Fraction of the heat from the motor inefficiencies that enters the fluid stream

<i>Units</i>	none
<i>Input Restrictions</i>	As designed. Default is 0.
<i>Standard Design</i>	Not applicable

#### **Cooling High Water Temperature**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The high temperature used for control. If the water temperature is above the high temperature, the control temperature is set to the low control temperature.
<i>Units</i>	Deg F
<i>Input Restrictions</i>	As Designed
<i>Standard Design</i>	Not applicable

#### **Cooling Low Water Temperature**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control of the water temperature. If the water temperature of the radiant cooling is below this temperature, cooling is disabled.
<i>Units</i>	Deg F
<i>Input Restrictions</i>	Fixed at 55°F
<i>Standard Design</i>	Not applicable

#### **Condensation Control Type**

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The simulation program may have a means of detecting when condensation is likely to occur on floor surfaces in the space. When this occurs, the simulation can shut off the system to prevent condensation from occurring.
<i>Units</i>	List: None, Simple, Variable
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

### **5.7.5.6 Chilled Beams**

Reserved. Building descriptors will be added to define how chilled beams can be modeled for the proposed design. Chilled beams are not applicable to the standard design system.

### **5.7.5.7 Ground-Source Heat Pumps**

Reserved. Building descriptors will be added to define how ground-source heat pumps can be modeled for the proposed design. Chilled beams are not applicable to the standard design system.

### **5.7.5.8 Variable Refrigerant Flow**

Reserved. Building descriptors will be added to define how VRF systems can be modeled for the proposed design. Chilled beams are not applicable to the standard design system.

### 5.7.5.9 Underfloor Air Distribution

Reserved. Building descriptors will be added to define how UFAD systems can be modeled for the proposed design. Chilled beams are not applicable to the standard design system.

## 5.7.6 Heating Systems

### 5.7.6.1 General

#### Heating Source

<i>Applicability</i>	All systems that provide heating
<i>Definition</i>	The source of heating for the heating and preheat coils. The choices are: <ul style="list-style-type: none"> <li>• Hot water</li> <li>• Steam</li> <li>• Electric resistance</li> <li>• Electric heat pump</li> <li>• Gas furnace</li> <li>• Gas heat pump (optional feature)</li> <li>• Oil furnace</li> <li>• Heat recovery (for preheat coils in proposed designs)</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Based on the prescribed system type. Refer to the HVAC System Map in Table 5. <b>Error! Reference source not found..</b>

Table 40 – Heating Source for Baseline Building

Baseline Building System	Heating Source
System 1 – PTAC	Gas Furnace
System 2 – FPFC	Hot water
System 3 – PSZ-AC	Gas or Oil Furnace
System 5 – Packaged VAV with Reheat	Hot water
System 6 – VAV with Reheat	Hot water
System 7 – Single Zone VAV	Gas or Oil Furnace
System 9 – Heating and Ventilation	Gas or Oil Furnace
System 10 – CRAH Unit, Data Center	None
System 11 – CRAC Unit, Data Center	None

### 5.7.6.2 Preheat Coil

If the proposed design has a preheat coil and it can be modeled in the baseline building system, then the baseline building also has a preheat coil sized to meet the preheat coil temperature specified for the proposed design.

**Preheat Coil Capacity**

<i>Applicability</i>	Systems with a preheat coil located in the outside air stream
<i>Definition</i>	The heating capacity of a preheating coil at design conditions.
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline building has a pre-heat coil when the proposed design has one. Autosize to maintain the preheat coil temperature of the proposed design.

**Preheat Coil Efficiency**

<i>Applicability</i>	Systems with a preheat coil with gas heating
<i>Definition</i>	The heating efficiency of a preheating coil at design conditions.
<i>Units</i>	Percentage
<i>Input Restrictions</i>	As designed. Default is 80%.
<i>Standard Design</i>	The baseline building has a pre-heat coil when the proposed design has one. Autosize to maintain the preheat coil temperature of the proposed design.

**5.7.6.3 Hydronic/Steam Heating Coils**

Systems with boilers have heating coils, including baseline building systems 1, 5 and 6 and 10.

**Heating Coil Capacity**

<i>Applicability</i>	All systems with a heating coil
<i>Definition</i>	The heating capacity of a heating coil at ARI conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed. Adjust the capacity if the number of unmet load hours exceeds 300.
<i>Standard Design</i>	Autosize with a heating oversizing factor of 25%. If the number of unmet load hours for the baseline exceeds, reduce the heating coil capacity as indicated in Section 2.6.2.

**5.7.6.4 Furnace****Furnace Capacity**

<i>Applicability</i>	Systems with a furnace
<i>Definition</i>	The full load heating capacity of the unit
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed. Adjust the capacity if the number of unmet load hours exceeds 300.
<i>Standard Design</i>	Autosize with an oversizing factor of 25% (let the software determine heating capacity based on the building loads). If the number of unmet load hours for the baseline exceeds 300, reduce the furnace capacity as indicated in Figure 2 and 2.6.2

**Furnace Fuel Heating Efficiency**

*Applicability*

Systems with a furnace

**Definition** The full load thermal efficiency of either a gas or oil furnace at design conditions. The software must accommodate input in either *Thermal Efficiency* ( $E_t$ ) or *Annual Fuel Utilization Efficiency* (AFUE). Where AFUE is provided,  $E_t$  shall be calculated as follows:

(36)

1) All Single Package Equipment

$$E_t = 0.005163 \times AFUE + 0.4033$$

2) Split Systems,  $AFUE \leq 83.5$

$$E_t = 0.002907 \times AFUE + 0.5787$$

3) Split Systems,  $AFUE > 83.5$

$$E_t = 0.011116 \times AFUE - 0.098185$$

where

AFUE The annual fuel utilization efficiency (%)

$E_t$  The thermal efficiency (fraction)

**Units** Fraction

**Input Restrictions** As designed

**Standard Design** The baseline efficiency requirement is located in Table E-3 of the 2009 Appliance Efficiency Standards. Use the heating input of the proposed design system to determine the size category.

#### Furnace Fuel Heating Part Load Efficiency Curve

**Applicability** Systems with furnaces

**Definition** An adjustment factor that represents the percentage of full load fuel consumption as a function of the percentage full load capacity. This curve shall take the form of a quadratic equation as follows:

(37)

$$Fuel_{partload} = Fuel_{rated} \times FHeatPLC$$

(38)

$$FHeatPLC = \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

where

FHeatPLC The Fuel Heating Part Load Efficiency Curve

$Fuel_{partload}$  The fuel consumption at part load conditions (Btu/h)

$Fuel_{rated}$  The fuel consumption at full load (Btu/h)

$Q_{partload}$  The capacity at part load conditions (Btu/h)

$Q_{rated}$  The capacity at rated conditions (Btu/h)

Table 41 – Furnace Efficiency Curve Coefficients

Coefficient	Furnace
a	0.0186100
b	1.0942090
c	-0.1128190

<i>Units</i>	Data structure
<i>Input Restrictions</i>	Fixed
<i>Standard Design</i>	Fixed

**Furnace Fuel Heating Pilot**

<i>Applicability</i>	Systems that use a furnace for heating
<i>Definition</i>	The fuel input for a pilot light on a furnace
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Zero (pilotless ignition)

**Furnace Fuel Heating Fan/Auxiliary**

<i>Applicability</i>	Systems that use a furnace for heating
<i>Definition</i>	The fan energy in forced draft furnaces and the auxiliary (pumps and outdoor fan) energy in fuel-fired heat pumps
<i>Units</i>	Kilowatts (kW)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**5.7.6.5 Electric Heat Pump****Electric Heat Pump Heating Capacity**

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The full load heating capacity of the unit, excluding supplemental heating capacity at ARI rated conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Autosize and use an oversizing factor of 25% (let the software determine heating capacity based on the building loads). The autosized equipment may need to be downsized to ensure that the number of unmet load hours do not exceed 300.

**Electric Heat Pump Supplemental Heating Source**

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The auxiliary heating source for a heat pump heating system. The common control sequence is to lock out the heat pump compressor when the supplemental heat is

activated. Other building descriptors may be needed if this is not the case. Choices for supplemental heat include:

- Electric resistance
- Gas furnace
- Oil furnace
- Hot water
- Other

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Electric resistance

### Electric Heat Pump Heating Efficiency

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The heating efficiency of a heat pump at ARI rated conditions as a dimensionless ratio of output over input. The software must accommodate user input in terms of either the <i>Coefficient of Performance</i> (COP) or the <i>Heating Season Performance Factor</i> (HSPF). Where HSPF is provided, COP shall be calculated as follows:

(39)

1) All Single Package Equipment

$$COP = 0.2778 \times HSPF + 0.9667$$

2) All Split Systems

$$COP = 0.4813 \times HSPF - 0.2606$$

For all unitary and applied equipment where the fan energy is part of the equipment efficiency rating, the COP shall be adjusted as follows to remove the fan energy:

(40)

$$COP_{adj} = \frac{\frac{HCAP_{rated}}{3.413} - BHP_{supply} \times 0.7457}{\frac{HCAP_{rated}}{COP \times 3.413} - BHP_{supply} \times 0.7457}$$

where

$COP_{adj}$  The adjusted coefficient of performance for simulation purposes

$COP$  The ARI rated coefficient of performance

$HCAP_{rated}$  The ARI rated heating capacity of a packaged unit (kBtu/h)

$BHP_{supply}$  The supply fan brake horsepower (bhp).

Refer to building descriptor *Supply Fan BHP*.

<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	

The minimum requirement is defined in Table 110.2-B of the Standards. Use the heating capacity of the proposed design to determine the size category.

#### Electric Heat Pump Heating Capacity Adjustment Curve(s)

**Applicability** All heat pumps

**Definition** A curve or group of curves that represent the available heat-pump heating capacity as a function of evaporator and condenser conditions. The default curves are given as follows:

$$Q_{available} = CAP\_FT \times Q_{rated} \quad (41)$$

$$CAP\_FT = a + b \times t_{odb} + c \times t_{odb}^2 + d \times t_{odb}^3 \quad (42)$$

For air-cooled heat pumps:

$$CAP\_FT = a + b \times t_{odb} + c \times t_{odb}^2 + d \times t_{odb}^3 \quad (43)$$

For water-cooled heat pumps:

$$CAP\_FT = a + b \times t_{db} + d \times t_{wt}$$

where

$Q_{available}$	Available heating capacity at present evaporator and condenser conditions (kBtu/h)
$t_{db}$	The entering coil dry-bulb temperature (°F)
$t_{wt}$	The water supply temperature (°F)
$t_{odb}$	The outside-air dry-bulb temperature (°F)
$Q_{rated}$	Rated capacity at ARI conditions (in kBtu/h)

Table 42 – Heat Pump Capacity Adjustment Curves (CAP-FT)

Coefficient	Water-Source	Air-Source
a	0.4886534	0.2536714
b	-0.0067774	0.0104351
c	N/A	0.0001861
d	0.0140823	-0.0000015

**Units** Data structure

**Input Restrictions** User may input curves or use default curves. If defaults are overridden, supporting documentation shall be provided.

(SEE 2.5.2.7 OF THE 2008 NACM)

For air-cooled heat pumps, the user may enter the heating capacity at two different outdoor dry-bulb temperatures: 17°F and 47°F. The compliance software shall be able to generate a curve-fit of the following data points for normalized capacity as a function of outside air dry-bulb temperature:

DATA	=	(67,1.337)
	=	(57,1.175)
	=	(47,1.000)
	=	(17,CAP17/CAP47)

$$= (7,0.702 \times \text{CAP17}/\text{CAP47})$$

$$= (-13, 0.153)$$

Standard Design Use default curves.

### Electric Heat Pump Heating Efficiency Adjustment Curve(s)

Applicability All heat pumps

Definition A curve or group of curves that varies the heat-pump heating efficiency as a function of evaporator conditions, condenser conditions and part-load ratio. The default curves are given as follows:

(44)

$$PLR = \frac{Q_{\text{operating}}}{Q_{\text{available}}(t_{\text{db}}, t_{\text{odb}}/wt)}$$

(45)

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

Air Source Heat Pumps:

(46)

$$EIR\_FT = a + b \times \left( \frac{t_{\text{odb}}}{t_{\text{db}}} \right) + c \times \left( \frac{t_{\text{odb}}}{t_{\text{db}}} \right)^2 + d \times \left( \frac{t_{\text{odb}}}{t_{\text{db}}} \right)^3$$

Water Source Heat Pumps:

(47)

$$EIR\_FT = a + b \times t_{\text{wt}} + d \times t_{\text{db}}$$

(48)

$$P_{\text{operating}} = P_{\text{rated}} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

where

$PLR$	Part load ratio based on available capacity (not rated capacity)
$EIR-FPLR$	A multiplier on the EIR of the heat pump as a function of part load ratio
$EIR-FT$	A multiplier on the EIR of the heat pump as a function of the wet-bulb temperature entering the coil and the outdoor dry-bulb temperature
$Q_{\text{operating}}$	Present load on heat pump (Btu/h)
$Q_{\text{available}}$	Heat pump available capacity at present evaporator and condenser conditions (Btu/h) .
$t_{\text{db}}$	The entering coil dry-bulb temperature (°F)
$t_{\text{wt}}$	The water supply temperature (°F)
$t_{\text{odb}}$	The outside air dry-bulb temperature (°F)
$P_{\text{rated}}$	Rated power draw at ARI conditions (kW)
$P_{\text{operating}}$	Power draw at specified operating conditions (kW)

**Table 43 – Heat Pump Heating Efficiency Adjustment Curves**

Coefficient	Air-and Water-Source EIR-FPLR	Water-Source EIR-FT	Air-Source EIR-FT
a	0.0856522	1.3876102	2.4600298
b	0.9388137	0.0060479	-0.0622539
c	-0.1834361	N/A	0.0008800
d	0.1589702	-0.0115852	-0.0000046

**Units** None

**Input Restrictions** User may input curves or use default curves. If defaults are overridden, documentation shall be provided.

The Compliance software shall be capable of generating a curve given user inputs of COP at 17°F and 47°F as follows:

DATA = (67,0.856)  
 = (57,0.919)  
 = (47,1.000)  
 = (17,COP47/COP17)  
 = (7,1.266×COP47/COP17)  
 = (-13, 3.428)

**Standard Design** Use default curves

#### **Electric Heat Pump Supplemental Heating Capacity**

**Applicability** All heat pumps

**Definition** The design heating capacity of a heat pump supplemental heating coil at ARI conditions

**Units** Btu/h

**Input Restrictions** As designed

**Standard Design** Autosize

#### **Electric Supplemental Heating Control Temp**

**Applicability** All heat pumps

**Definition** The outside dry-bulb temperature below which the heat pump supplemental heating is allowed to operate

**Units** Degrees Fahrenheit (°F)

**Input Restrictions** As designed. Default to 40°F

**Standard Design** 40°F

#### **Heat Pump Compressor Minimum Operating Temp**

**Applicability** All heat pumps

**Definition** The outside dry-bulb temperature below which the heat pump compressor is disabled

**Units** Degrees Fahrenheit (°F)

**Input Restrictions** As designed. Default to 17°F

**Standard Design** 17°F

**Coil Defrost**

<i>Applicability</i>	Air-cooled electric heat pump
<i>Definition</i>	The defrost control mechanism for an air-cooled heat pump. The choices are: <ul style="list-style-type: none"> <li>• Hot-gas defrost, on-demand</li> <li>• Hot-gas defrost, timed 3.5 minute cycle</li> <li>• Electric resistance defrost, on-demand</li> <li>• Electric resistance defrost, timed 3.5 minute cycle</li> </ul> Defrost shall be enabled whenever the outside air dry-bulb temperature drops below 40°F.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	Default to use hot-gas defrost, timed 3.5 minute cycle. User may select any of the above.
<i>Standard Design</i>	The baseline building uses the default. <b>NOTE: THIS IS NOT DEFINED IN THE T24-2008 NACM.</b>

**Coil Defrost kW**

<i>Applicability</i>	Heat pumps with electric resistance defrost
<i>Definition</i>	The capacity of the electric resistance defrost heater
<i>Units</i>	Kilowatts (kW)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 0 if nothing is entered.
<i>Standard Design</i>	Not applicable. Baseline building systems 2 and 4 use hot-gas, timed 3.5 minute cycle.

**Crank Case Heater kW**

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The capacity of the electric resistance heater in the crank case of a direct expansion (DX) compressor. The crank case heater operates only when the compressor is off.
<i>Units</i>	Kilowatts (kW)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 0.1 if nothing is entered.
<i>Standard Design</i>	Zero (0)

**Crank Case Heater Shutoff Temperature**

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The outdoor air dry-bulb temperature above which the crank case heater is not permitted to operate.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 50°F.
<i>Standard Design</i>	50°F

### 5.7.6.6 Heat Recovery

#### Exhaust Air Sensible Heat Recovery Effectiveness

**Applicability** Any system with outside air heat recovery

**Definition** The effectiveness of an air-to-air heat exchanger between the building exhaust and entering outside air streams. Effectiveness is defined as follows:

(49)

$$HREFF = \frac{(EEA_{db} - ELA_{db})}{(EEA_{db} - OSA_{db})}$$

where

HREFF The air-to-air heat exchanger effectiveness

EEA<sub>db</sub> The exhaust air dry-bulb temperature entering the heat exchanger

ELA<sub>db</sub> The exhaust air dry-bulb temperature leaving the heat exchanger

OSA<sub>db</sub> The outside air dry-bulb temperature

**Units** Ratio between 0 and 1

**Input Restrictions** As designed

**Standard Design** Not applicable

#### Exhaust Air Latent Heat Recovery Effectiveness

**Applicability** Any system with outside air enthalpy heat recovery

**Definition** The latent heat recovery effectiveness of an air-to-air heat exchanger between the building exhaust and entering outside air streams. Effectiveness is defined as follows:

(50)

$$HREFF = \frac{(EEA_w - ELA_w)}{(EEA_w - OSA_w)}$$

where

HREFF The air-to-air heat exchanger effectiveness

EEA<sub>w</sub> The exhaust air humidity ratio (fraction of mass of moisture in air to mass of dry air) entering the heat exchanger

ELA<sub>db</sub> The exhaust air humidity ratio leaving the heat exchanger

OSA<sub>db</sub> The outside air humidity ratio

Note that for sensible heat exchangers this term is not applicable.

**Units** Ratio between 0 and 1

**Input Restrictions** As designed

**Standard Design** Not applicable

#### Condenser Heat Recovery Effectiveness

**Applicability** Systems that use recover heat from a condenser

<i>Definition</i>	The percentage of heat rejection at design conditions from a DX or heat pump unit in cooling mode that is available for space or water heating.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.
<i>Standard Design</i>	Not applicable

#### **Heat Recovery Use**

<i>Applicability</i>	Systems that use heat recovery
<i>Definition</i>	The end use of the heat recovered from a DX or heat pump unit. The choices are: <ul style="list-style-type: none"> <li>• Reheat coils</li> <li>• Water heating</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.
<i>Standard Design</i>	Not applicable

## **5.7.7 Humidity Controls and Devices**

### **5.7.7.1 General**

#### **Humidifier Type**

<i>Applicability</i>	Optional humidifier
<i>Definition</i>	The type of humidifier employed. Choices include: <ul style="list-style-type: none"> <li>• Hot-Water</li> <li>• Steam</li> <li>• Electric</li> <li>• Evaporative Humidification</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Evaporative Humidification (for computer rooms and data centers)

#### **Humidistat Maximum Setting**

<i>Applicability</i>	Systems with humidity control
<i>Definition</i>	The control setpoint for dehumidification
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

**Humidistat Minimum Setting**

<i>Applicability</i>	Systems with humidity control
<i>Definition</i>	The control setpoint for humidification
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as proposed design

**5.7.7.2 Desiccant****Desiccant Type**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	<p>Describes the configuration of desiccant cooling equipment</p> <p>The following configurations for desiccant systems are allowed:</p> <ul style="list-style-type: none"> <li>• LIQ-VENT-AIR1 – a liquid desiccant dehumidifying unit</li> <li>• LIQ-VENT-AIR2 – a liquid desiccant dehumidifying unit combined with a gas-fired absorption chiller</li> <li>• SOL-VENT-AIR1 – a solid desiccant dehumidifying unit</li> <li>• NO-DESICCANT – the default, which indicates that no desiccant system is present</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Desiccant Control Mode**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	<p>The method of controlling the operation of the desiccant unit. For liquid-based systems this can be either:</p> <ul style="list-style-type: none"> <li>• Dry-bulb – the desiccant unit is turned on whenever the outside air dry-bulb exceeds a set limit.</li> <li>• Evaporative cooling– cycles the desiccant unit on when an evaporative cooler is on to maintain a dewpoint setpoint.</li> <li>• Dewpoint – cycles the desiccant unit on and off to maintain the dewpoint temperature of the supply air.</li> </ul> <p>For solid-based systems the following configurations are possible:</p> <ul style="list-style-type: none"> <li>• Dehumidification only – the desiccant unit cycles on and off to maintain indoor humidity levels</li> <li>• Sensible heat exchanger plus regeneration – the desiccant unit includes a sensible heat exchanger to precool the hot, dry air leaving the desiccant unit. The air leaving the exhaust side of the heat exchanger is directed to the desiccant unit</li> <li>• Sensible heat exchanger – the desiccant unit includes a heat exchanger, but the air leaving the exhaust side of the heat exchanger is exhausted to the outdoors</li> </ul>

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Desiccant Air Fraction**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The fraction of the supply air that passes through the desiccant unit. Typically either the minimum outside air fraction or all of the air passes through the desiccant system.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Desiccant Heat Source**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The source of heat that is used to dry out the desiccant. This can be either: <ul style="list-style-type: none"> <li>Gas – Hydronic – the regeneration heat load is met with a gas-fired heater</li> <li>Hot water – the heat load is met with hot water from the plant</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Liquid Desiccant Performance Curves**

<i>Applicability</i>	Systems with liquid-based desiccant dehumidification
<i>Definition</i>	A set of performance curves that apply to liquid desiccant systems.

$$\bullet \quad \text{DESC} - T - \text{FTW} = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (51)$$

$$\bullet \quad \text{DESC} - W - \text{FTW} = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (52)$$

$$\bullet \quad \text{DESC} - \text{Gas} - \text{FTW} = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (53)$$

$$\bullet \quad \text{DESC} - \text{kW} - \text{FTW} = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (54)$$

where

DESC-T-FTW	temperature leaving desiccant unit
DESC-W-FTW	humidity ratio leaving desiccant unit
DESC-Gas-FTW	Gas usage of desiccant unit
DESC-kW-FTW	Electric usage of desiccant unit

T	entering air temperature
w	entering humidity ratio

**Table 44 – Liquid Desiccant Unit Performance Curves**

Coefficient	DESC-T-FTW	DESC-W-FTW	DESC-Gas-FTW	DESC-kW-FTW
a	11.5334997	11.8993998	58745.8007813	3.5179000
b	0.6586730	-0.2695580	-1134.4899902	-0.0059317
c	-0.0010280	0.0044549	-3.6676099	0.0000000
d	0.2950410	0.0830525	3874.5900879	0.0040401
e	-0.0001700	0.0006974	-1.6962700	0.0000000
f	-0.0008724	0.0015879	-13.0732002	0.0000000

<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed, default to values in Table 44
<i>Standard Design</i>	Not applicable

**Desiccant Dewpoint Temperature Setpoint**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The setpoint dewpoint temperature of the air leaving the desiccant system
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Defaults to 50°F.
<i>Standard Design</i>	Not applicable

**Desiccant Heat Exchanger Effectiveness**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The effectiveness of a sensible heat exchanger used with a desiccant system
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Desiccant Heat Exchanger Pressure Drop**

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The pressure drop across a sensible heat exchanger used with a desiccant system
<i>Units</i>	in. H <sub>2</sub> O
<i>Input Restrictions</i>	As designed. Defaults to 1.0 in. H <sub>2</sub> O
<i>Standard Design</i>	Not applicable

## 5.8 HVAC Primary Systems

### 5.8.1 Boilers

#### Boiler Name

<i>Applicability</i>	All boilers
<i>Definition</i>	A unique descriptor for each boiler, heat pump, central heating heat-exchanger or heat recovery device.
<i>Units</i>	None
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans for the proposed design.
<i>Standard Design</i>	Boilers are only designated in the baseline model if the Baseline System is of type 1 (PTAC), type 5 (Packages VAV with Reheat) or type 6 (VAV with Reheat).

#### Boiler Fuel

<i>Applicability</i>	All boilers
<i>Definition</i>	The fuel source for the central heating equipment. The choices are: <ul style="list-style-type: none"> <li>• Gas</li> <li>• Oil</li> <li>• Electricity</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same fuel as the proposed design

#### Boiler Type

<i>Applicability</i>	All boilers
<i>Definition</i>	The boiler type. Choices include: <ul style="list-style-type: none"> <li>• Steam Boiler</li> <li>• Hot Water Boiler</li> <li>• Heat-Pump Water Heater</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The boiler type will be a hot water boiler for baseline systems 1, 5 and 7 All other system types do not have a boiler.

#### Boiler Draft Type

<i>Applicability</i>	All boilers
<i>Definition</i>	

How combustion airflow is drawn through the boiler. Choices are:

- Natural (sometimes called atmospheric)
- Mechanical

Natural draft boilers use natural convection to draw air for combustion through the boiler. Natural draft boilers are subject to outside air conditions and the temperature of the flue gases.

Mechanical draft boilers enhance the air flow in one of three ways: 1) Induced draft, which uses ambient air, a steam jet, or a fan to induce a negative pressure which pulls flow through the exhaust stack; 2) Forced draft, which uses a fan and ductwork to create a positive pressure that forces air into the furnace, and 3) Balanced draft, which uses both induced draft and forced draft methods to bring air through the furnace, usually keeping the pressure slightly below atmospheric.

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Mechanical (forced).

#### **Number of Identical Boiler Units**

<i>Applicability</i>	All boilers
<i>Definition</i>	The number of identical units for staging
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed. Default is 1.
<i>Standard Design</i>	The baseline building shall have one boiler for a when the baseline plant serves a conditioned floor area of 15,000 ft <sup>2</sup> or less, and have two equally size boilers for plants serving more than 15,000 ft <sup>2</sup> .

#### **Boiler Heat Loss**

<i>Applicability</i>	All boilers
<i>Definition</i>	The boiler or heat-exchanger heat loss expressed as a percentage of full load output capacity. This loss only occurs when the boiler is firing.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	Default is 2% for electric boilers and heat-exchangers and 0% for fuel-fired boilers. <b>If the user overrides the default, supporting documentation is required.</b>
<i>Standard Design</i>	Prescribed at 2% for electric boilers and heat-exchangers. Prescribed at 0% for fuel-fired boilers, since this loss is already incorporated into the overall thermal efficiency, combustion efficiency or AFUE of the boiler. <b>(THIS IS NOT EXPLICITLY MENTIONED IN THE 2008 T24 ACM.)</b>

#### **Boiler Design Capacity**

<i>Applicability</i>	All boilers
<i>Definition</i>	The heating capacity at design conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	Unmet load hours shall not exceed 300. If they do, the proposed boiler capacity shall be increased incrementally until the unmet loads are reduced to 300 or less.

<i>Standard Design</i>	The boiler is sized to be 25% larger than the peak loads of the baseline building. Baseline boilers shall be sized using weather files containing 99.6% heating design temperatures and 0.5% dry-bulb and 1% wet-bulb cooling design temperatures.
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### Boiler Efficiency Type

<i>Applicability</i>	All boilers
<i>Definition</i>	<p>The full load efficiency of a boiler is expressed as one of the following:</p> <ul style="list-style-type: none"> <li>• <i>Annual Fuel Utilization Efficiency</i> (AFUE) is a measure of the boiler's efficiency over a predefined heating season.</li> <li>• <i>Thermal Efficiency</i> (<math>E_t</math>) is the ratio of the heat transferred to the water divided by the heat input of the fuel.</li> <li>• <i>Combustion Efficiency</i> (<math>E_c</math>) is the measure of how much energy is extracted from the fuel and is the ratio of heat transferred to the combustion air divided by the heat input of the fuel.</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	<p><i>Annual Fuel Utilization Efficiency</i> (AFUE), for all gas and oil-fired boilers with less than 300,000 Btu/h capacity.</p> <p><i>Thermal Efficiency</i> (<math>E_t</math>), for all gas and oil-fired boilers with capacities between 225,000 and 2,500,000 Btu/h.</p> <p><i>Combustion Efficiency</i> (<math>E_c</math>), for all gas and oil-fired boilers with capacities above 2,500,000 Btu/h.</p>
<i>Standard Design</i>	Same as proposed design

### Boiler Efficiency

<i>Applicability</i>	All boilers
<i>Definition</i>	<p>The full load efficiency of a boiler at rated conditions (see efficiency type above) expressed as a dimensionless ratio of output over input. The software must accommodate input in either <i>Thermal Efficiency</i> (<math>E_t</math>) or <i>Annual Fuel Utilization Efficiency</i> (AFUE). Where AFUE is provided, <math>E_t</math> shall be calculated as follows:</p> <div style="text-align: right;">(55)</div> $\begin{aligned} &1) 75\% \leq \text{AFUE} < 80\% \\ &\quad E_t = 0.1 \times \text{AFUE} + 72.5\% \\ &2) 80\% \leq \text{AFUE} \leq 100\% \\ &\quad E_t = 0.875 \times \text{AFUE} + 10.5\% \end{aligned}$ <p>All electric boilers will have an efficiency of 100%.</p> <p>For applicable software, heat input ratio shall be defined as the inverse of thermal efficiency.</p>
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Boilers for the baseline design are assumed to have the minimum efficiency as listed in Table E-4 of the 2009 CEC Appliance Efficiency Standards.

**Boiler Part-Load Performance Curve**

**Applicability** All boilers

**Definition** An adjustment factor that represents the percentage full load fuel consumption as a function of the percentage full load capacity. This curve shall take the form of a quadratic equation as follows:

(56)

$$Fuel_{partload} = Fuel_{design} \times FHeatPLC(Q_{partload}, Q_{rated})$$

$$FHeatPLC = \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

where

FHeatPLC	The Fuel Heating Part Load Efficiency Curve
Fuel <sub>partload</sub>	The fuel consumption at part load conditions (Btu/h)
Fuel <sub>design</sub>	The fuel consumption at design conditions (Btu/h)
Q <sub>partload</sub>	The boiler capacity at part load conditions (Btu/h)
Q <sub>rated</sub>	The boiler capacity at design conditions (Btu/h)
a	Constant, 0.082597
b	Constant, 0.996764
c	Constant, -0.079361

**Units** Ratio

**Input Restrictions** As designed. If the user does not use the default curve, supporting documentation is required. The software may auto-generate curves for other boiler types from descriptive type information such as boiler type, core, full or partial condensing, combustion air control, minimum unloading or staging, and return water temperature.

**Standard Design** The baseline building uses the default

**Boiler Minimum Unloading Ratio**

**Applicability** All boilers

**Definition** The minimum unloading capacity of a boiler expressed as a percentage of the rated capacity. Below this level the boiler must cycle to meet the load.

**Table 45 – Default Minimum Unloading Ratios**

Boiler Type	Default Unloading Ratio
Electric Steam	1%
Electric Hot Water	1%
Fuel-Fired Steam	25%
Fuel-Fired Hot Water	25%

**Units** Percent (%)

**Input Restrictions** As designed. If the user does not use the default value the software must indicate that supporting documentation is required on the output forms.

**Standard Design** Use defaults.

**Hot Water Supply Temperature**

<i>Applicability</i>	All boilers
<i>Definition</i>	The temperature of the water produced by the boiler and supplied to the hot water loop
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Use 180°F for baseline boiler

**Hot Water Return Temperature**

<i>Applicability</i>	All boilers
<i>Definition</i>	The temperature of the water returning to the boiler from the hot water loop
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Use 130°F for baseline boiler design.

**Hot Water Supply Temperature Reset**

<i>Applicability</i>	All boilers
<i>Definition</i>	Variation of the hot water supply temperature with outdoor air temperature.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**5.8.2 Chillers****Chiller Name**

<i>Applicability</i>	All chillers
<i>Definition</i>	A unique descriptor for each chiller
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Standard Design</i>	Chillers are only designated when the baseline system is of type 5 (VAV with reheat)

**Chiller Type**

<i>Applicability</i>	All chillers
<i>Definition</i>	<p>The type of chiller, either a vapor-compression chiller or an absorption chiller.</p> <p>Vapor compression chillers operate on the reverse-Rankine cycle, using mechanical energy to compress the refrigerant, and include:</p> <ul style="list-style-type: none"> <li>•</li> <li>• Positive displacement – includes reciprocating (piston-style), scroll and screw compressors</li> <li>• Centrifugal – uses rotating impeller blades to compress the air and impart velocity</li> </ul>

- Single Effect Absorption – use a single generator & condenser
- Double Effect Absorption – use two generators/concentrators and condensers, one at a lower temperature and the other at a higher temperature. It is more efficient than the single effect, but it must use a higher temperature heat source.
- Double Effect Absorption, Indirect-Fired
- Gas Engine Driven Chiller

*Units* List (see above)

*Input Restrictions* As designed

*Standard Design* The baseline building chiller is based on the design capacity of the proposed design as follows:

*Table 46 – Type and Number of Chillers*

Building Peak Cooling Load	Number and Type of Chiller(s)
<= 300 tons	1 water-cooled screw chiller
>300 tons, < 600 tons	2 water-cooled screw chillers, sized equally
>= 600 tons	A minimum of two (2) water-cooled centrifugal chillers, sized to keep the unit size below 800 tons

#### **Number of Identical Chiller Units**

*Applicability* All chillers

*Definition* The number of identical units for staging.

*Units* None

*Input Restrictions* As designed. Default is 1.

*Standard Design* From Table 46 above, there is one chiller if the baseline system cooling load is 300 tons or less and two equally sized chillers for baseline system loads between 300 and 600 tons. For loads above 600 tons, two or more chillers of equal size are used, with no chiller larger than 800 tons.

#### **Chiller Fuel**

*Applicability* All chillers

*Definition* The fuel source for the chiller. The choices are:

- Electricity (for all vapor-compression chillers)
- Gas (Absorption units only, designated as direct-fired units)
- Oil (Absorption units only, designated as direct-fired units)
- Hot Water (Absorption units only, designated as indirect-fired units)
- Steam (Absorption units only, designated as indirect-fired units)

*Units* List (see above)

*Input Restrictions* As designed.

*Standard Design* Electricity

**Chiller Rated Capacity**

<i>Applicability</i>	All chillers
<i>Definition</i>	The cooling capacity of a piece of heating equipment at rated conditions.
<i>Units</i>	Btu/h or tons
<i>Input Restrictions</i>	As designed. If unmet load hours are greater than 300, the chiller may have to be made larger.
<i>Standard Design</i>	Determine loads for baseline building and oversize by 15%.

**Chiller Rated Efficiency**

<i>Applicability</i>	All chillers
<i>Definition</i>	The Efficiency of the chiller (Coefficient of Performance (COP) for air-cooled chillers and kW/ton for water-cooled, positive displacement chillers) at ARI 550/590 rated full-load conditions.
<i>Units</i>	Ratio (kW/ton or COP)
<i>Input Restrictions</i>	As designed. Must meet the minimum requirements of Table 110.2-D.
<i>Standard Design</i>	Use the minimum efficiency requirements from Tables 110.2-D Path B.

**Integrated Part-Load Value**

<i>Applicability</i>	All chillers
<i>Definition</i>	The part-load efficiency of a chiller developed from a weighted average of four rating conditions, according to ARI Standard 550..
<i>Units</i>	Ratio (kW/ton)
<i>Input Restrictions</i>	As designed. Must meet the minimum requirements of Table 110.2-D.
<i>Standard Design</i>	Not used. The proposed design input for IPLV, along with the Chiller Rated Efficiency, determines whether the chiller performance curves will use Path A or Path B.

**Chiller Minimum Unloading Ratio**

<i>Applicability</i>	All chillers
<i>Definition</i>	The minimum unloading capacity of a chiller expressed as a fraction of the rated capacity. Below this level the chiller must cycle to meet the load.

**Table 47 – Default Minimum Unloading Ratios**

Chiller Type	Default Unloading Ratio
Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed. If the user does not employ the default values, supporting documentation is required.
<i>Standard Design</i>	Use defaults listed above.

**Chiller Cooling Capacity Adjustment Curve**

*Applicability* All chillers

*Definition* A curve or group of curves or other functions that represent the available total cooling capacity as a function of evaporator and condenser conditions and perhaps other operating conditions. The default curves are given as follows:

$$Q_{available} = CAP\_FT \times Q_{rated} \quad (57)$$

For air-cooled chillers:

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{chws} \times t_{odb} \quad (58)$$

For water-cooled chillers:

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws} \quad (59)$$

where

$Q_{available}$  Available cooling capacity at present evaporator and condenser conditions (MBH)

$t_{chws}$  The chilled water supply temperature (°F)

$t_{cws}$  The condenser water supply temperature (°F)

$t_{odb}$  The outside air dry-bulb temperature (°F)

$Q_{rated}$  Rated capacity at ARI conditions (MBH)

Note: If an air-cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

Separate curves are provided for Path A and Path B chillers in Appendix 5.7.

**Table 48 – Default Capacity Coefficients – Electric Air-Cooled Chillers**

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.40070684	0.57617295	-0.09464899	N/A
b	0.01861548	0.02063133	0.03834070	N/A
c	0.00007199	0.00007769	-0.00009205	N/A
d	0.00177296	-0.00351183	0.00378007	N/A
e	-0.00002014	0.00000312	-0.00001375	N/A
f	-0.00008273	-0.00007865	-0.00015464	N/A

**Table 49 – Default Capacity Coefficients – Electric Water-Cooled Chillers**

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.36131454	0.58531422	0.33269598	-0.29861976
b	0.01855477	0.01539593	0.00729116	0.02996076
c	0.00003011	0.00007296	-0.00049938	-0.00080125
d	0.00093592	-0.00212462	0.01598983	0.01736268
e	-0.00001518	-0.00000715	-0.00028254	-0.00032606
f	-0.00005481	-0.00004597	0.00052346	0.00063139

**Table 50 – Default Capacity Coefficients – Fuel- & Steam-Source Water-Cooled Chillers**

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption	Engine Driven Chiller
A	0.723412	-0.816039	1.000000	0.573597
B	0.079006	-0.038707	0.000000	0.0186802
C	-0.000897	0.000450	0.000000	0.000000
D	-0.025285	0.071491	0.000000	-0.00465325
E	-0.000048	-0.000636	0.000000	0.000000
F	0.000276	0.000312	0.000000	0.000000

**Units** Data structure

**Input Restrictions** Default curves are provided in Appendix 5.7. If the default curves are overridden, supporting documentation is required.

**Standard Design** Use default curve for Path A and Path B chiller as applicable.

#### **Electric Chiller Cooling Efficiency Adjustment Curves**

**Applicability** All chillers

**Definition** A curve or group of curves that varies the cooling efficiency of an electric chiller as a function of evaporator conditions, condenser conditions and part-load ratio. Note that for variable-speed chillers, the part-load cooling efficiency curve is a function of both part-load ratio and leaving condenser water temperature. The default curves are given as follows:

(60)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{chws}, t_{cws / odb})}$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$\text{variable - speed } EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times PLR \cdot t_{cws} + g \times PLR^3 + h \times t_{cws}^3 + i \times PLR^2 \cdot t_{cws} + j \times t_{cws}^2 \cdot PLR$$

$$\text{air - cooled } EIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{chws} \times t_{odb}$$

$$\text{water - cooled } EIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws}$$

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

where

$PLR$	Part load ratio based on available capacity (not rated capacity)
$Q_{operating}$	Present load on chiller (Btu/h)
$Q_{available}$	Chiller available capacity at present evaporator and condenser conditions (Btu/h)
$t_{chws}$	The chilled water supply temperature (°F)
$t_{cws}$	The condenser water supply temperature (°F)
$t_{odb}$	The outside air dry-bulb temperature (°F)
$P_{rated}$	Rated power draw at ARI conditions (kW)
$P_{operating}$	Power draw at specified operating conditions (kW)

Note: If an air-cooled chiller employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

**Table 51 – Default Efficiency EIR-FT Coefficients – Air-Cooled Chillers**

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.99006553	0.66534403	0.13545636	N/A
b	-0.00584144	-0.01383821	0.02292946	N/A
c	0.00016454	0.00014736	-0.00016107	N/A
d	-0.00661136	0.00712808	-0.00235396	N/A
e	0.00016808	0.00004571	0.00012991	N/A
f	-0.00022501	-0.00010326	-0.00018685	N/A

**Table 52 – Default Efficiency EIR-FT Coefficients – Water-Cooled Chillers**

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	1.00121431	0.46140041	0.66625403	0.51777196
b	-0.01026981	-0.00882156	0.00068584	-0.00400363
c	0.00016703	0.00008223	0.00028498	0.00002028
d	-0.00128136	0.00926607	-0.00341677	0.00698793
e	0.00014613	0.00005722	0.00025484	0.00008290
f	-0.00021959	-0.00011594	-0.00048195	-0.00015467

**Table 53 – Default Efficiency EIR-FPLR Coefficients – Air-Cooled Chillers**

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.06369119	0.11443742	0.03648722	N/A
b	0.58488832	0.54593340	0.73474298	N/A
c	0.35280274	0.34229861	0.21994748	N/A

**Table 54 – Default Efficiency EIR-FPLR Coefficients – Water-Cooled Chillers**

Coefficient	Scroll	Reciprocating	Screw	Centrifugal	Variable-Speed
a	0.04411957	0.08144133	0.33018833	0.17149273	TBD
b	0.64036703	0.41927141	0.23554291	0.58820208	TBD
c	0.31955532	0.49939604	0.46070828	0.23737257	TBD
d	0	0	0	0	TBD
e	0	0	0	0	TBD
f	0	0	0	0	TBD
g	0	0	0	0	TBD
h	0	0	0	0	TBD
i	0	0	0	0	TBD
j	0	0	0	0	TBD

**Units** Data structure

**Input Restrictions** Default curves are specified in Appendix 5.7. **If defaults are overridden, supporting documentation is required.**

**Standard Design** Use default curves. A separate set of curves will be provided for Path A water-cooled chillers and Path B water-cooled chillers. The Path is determined by comparing software inputs of full-load efficiency and integrated part-load value with the requirements of Standards Table 110.2-D.

#### **Fuel and Steam Chiller Cooling Efficiency Adjustment Curves**

**Applicability** All chillers

**Definition** A curve or group of curves that varies the cooling efficiency of a fuel-fired or steam

chiller as a function of evaporator conditions, condenser conditions, and part-load ratio. The default curves are given as follows:

Default Curves for Steam-Driven Single and Double Effect Absorption Chillers

(61)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{chws}, t_{cws} / odb)}$$

$$FIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$FIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws}$$

$$Fuel_{partload} = Fuel_{rated} \times FIR\_FPLR \times FIR\_FT \times CAP\_FT$$

Default Curves for Direct-Fired Double Effect Absorption Chillers

(62)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{chws}, t_{cws} / odb)}$$

$$FIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$FIR\_FT1 = a + b \times t_{chws} + c \times t_{chws}^2$$

$$FIR\_FT2 = d + e \times t_{cws} + f \times t_{cws}^2$$

$$Fuel_{partload} = Fuel_{rated} \times FIR\_FPLR \times FIR\_FT1 \times FIR\_FT2 \times CAP\_FT$$

The default curves for engine driven chillers are the same format as those for the Steam-Driven Single and Double Effect Absorption Chillers but there are three sets of curves for different ranges of operation based on the engine speed.

where

$PLR$	Part load ratio based on available capacity (not rated capacity)
$FIR\_FPLR$	A multiplier on the fuel input ratio (FIR) to account for part load conditions
$FIR\_FT$	A multiplier on the fuel input ratio (FIR) to account for the chiller water supply temperature and the condenser water temperature
$FIR\_FT1$	A multiplier on the fuel input ratio (FIR) to account for chilled water supply temperature
$FIR\_FT2$	A multiplier on the fuel input ratio (FIR) to account for condenser water supply temperature
$CAP\_FT$	A multiplier on the capacity of the chiller (see Equation (58))
$Q_{operating}$	Present load on chiller (in Btu/h)
$Q_{available}$	Chiller available capacity at present evaporator and condenser conditions (in Btu/h)
$t_{chws}$	The chilled water supply temperature (in °F)
$t_{cws}$	The condenser water supply temperature (in °F)
$t_{odb}$	The outside air dry-bulb temperature (°F)
$Fuel_{rated}$	Rated fuel consumption at ARI conditions (in Btu/h)
$Fuel_{partload}$	Fuel consumption at specified operating conditions (in Btu/h)

**Table 55 – Default FIR-FPLR coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers**

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption
a	0.098585	0.013994	0.13551150
b	0.583850	1.240449	0.61798084
c	0.560658	-0.914883	0.24651277
d	-0.243093	0.660441	0.00000000

**Table 56 – Default FIR-FPLR coefficients – Engine Driven Chillers**

Coefficient	%Speed≤Min.	%Speed>Min. %Speed<60%	%Speed>60%
a	0.3802	1.14336	1.38861
b	2.3609	0.022889	-0.388614
c	0.0000	0.0000	0.0000
d	0.0000	0.0000	0.0000

**Table 57 – Default FIR-FT coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers**

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption
a	0.652273	1.658750	4.42871284
b	0.000000	0.000000	-0.13298607
c	0.000000	0.000000	0.00125331
d	-0.000545	-0.290000	0.86173749
e	0.000055	0.000250	-0.00708917
f	0.000000	0.000000	0.0010251

**Table 58 – Default FIR-FT coefficients – Engine Driven Chillers**

Coefficient	%Speed≤Min.	%Speed>Min. %Speed<60%	%Speed>60%
A	1.0881500	1.2362400	1.2362400
B	0.0141064	0.0168923	0.0168923
C	0.0000000	0.0000000	0.0000000
D	-0.00833912	-0.0115235	-0.0115235
E	0.0000000	0.0000000	0.0000000
F	0.0000000	0.0000000	0.0000000

**Units** Data structure

**Input Restrictions** User may input curves or use default curves. If defaults are overridden, supporting documentation is required.

**Standard Design** Use default curves.

### Chilled Water Supply Temperature

**Applicability** All chillers

**Definition** The chilled water supply temperature of the chiller at design conditions

**Units** Degrees Fahrenheit (°F)

**Input Restrictions** As designed

**Standard Design**

The baseline chilled water supply temperature is set to 44°F.

#### **Chilled Water Return Temperature**

<i>Applicability</i>	All chillers
<i>Definition</i>	The chilled water return temperature setpoint
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline chilled water return temperature is set to 64°F.

#### **Chilled Water Supply Temperature Reset**

<i>Applicability</i>	All chillers
<i>Definition</i>	The reset schedule for the chilled water supply temperature. The chilled water setpoint may be reset based on demand or outdoor air temperature.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed..
<i>Standard Design</i>	Demand-based reset, up to 10°F from design chilled water supply temperature

#### **Condenser Type**

<i>Applicability</i>	All chillers
<i>Definition</i>	<p>The type of condenser for a chiller. The choices are:</p> <ul style="list-style-type: none"> <li>• Air-Cooled</li> <li>• Water-Cooled</li> <li>• Evaporatively-Cooled</li> </ul> <p>Air-cooled chillers use air to cool the condenser coils. Water-cooled chillers use cold water to cool the condenser and additionally need either a cooling tower or a local source of cold water. Evaporatively-cooled chillers are similar to air-cooled chillers, except they use a water mist to cool the condenser coil which makes them more efficient.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline chiller is always assumed to have a water-cooled condenser, although the chiller type will change depending on the design capacity.

#### **Air-Cooled Condenser Power**

<i>Applicability</i>	All chillers with air-cooled condensers where fan energy is not part of the COP.
<i>Definition</i>	The energy usage of the condenser fan(s) at design conditions on an air-cooled chiller. This unit should only be used for chillers composed of separate evaporator and condenser sections where the fan energy is not part of the chiller COP.
<i>Units</i>	Kilowatts (kW)
<i>Input Restrictions</i>	As designed. The user must enter data for remote air-cooled condensing units.
<i>Standard Design</i>	Not applicable, since all baseline chillers have water-cooled condensers.

### 5.8.3 Cooling Towers

**Baseline Building Summary.** Baseline building system 6 has one or more cooling towers. One tower is assumed to be matched to each baseline building chiller. Each baseline building chiller has its own condenser water pump that operates when the chiller is brought into service. The range between the condenser water return (CWR) and condenser water supply (CWS) is 12 F. The baseline building pumping energy is assumed to be 12 W/gpm. The baseline building cooling tower is assumed to have a variable-speed fan that is controlled to provide a CWS equal to the design dry-bulb temperature when weather permits. The tower fan modulates to maintain a CWS of the design wet-bulb temperature at low wet-bulb conditions. Under cooling conditions closer to design conditions, the CWS floats up to a maximum of 85 F (the design condition).

#### Cooling Tower Name

<i>Applicability</i>	All cooling towers
<i>Definition</i>	A unique descriptor for each cooling tower
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Standard Design</i>	Descriptive name that keys the baseline building plant

#### Cooling Tower Type

<i>Applicability</i>	All cooling towers
<i>Definition</i>	<p>The type of cooling tower employed. The choices are:</p> <ul style="list-style-type: none"> <li>• Open tower, centrifugal fan</li> <li>• Open tower, axial fan</li> <li>• Closed tower, centrifugal fan</li> <li>• Closed tower, axial fan</li> </ul> <p>Open cooling towers collect the cooled water from the tower and pump it directly back to the cooling system. Closed towers circulate the evaporated water over a heat exchanger to indirectly cool the system fluid.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline cooling tower is an open tower axial fan device

#### Cooling Tower Capacity

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The tower thermal capacity per cell adjusted to CTI (Cooling Technology Institute) rated conditions of 95 F condenser water return, 85 F condenser water supply, and 78 F wet-bulb with a 3 gpm/nominal ton water flow. The default cooling tower curves below are at unity at these conditions.
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline building chiller is autosized and increased by 15%. The tower is sized to supply 85 F condenser water at design conditions for the oversized chiller.

**Cooling Tower Number of Cells**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The number of cells in the cooling tower. Each cell will be modeled as equal size. Cells are subdivisions in cooling towers into individual cells, each with their own fan and water flow, and allow the cooling system to respond more efficiently to lower load conditions.
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design.

**Cooling Tower Total Fan Horse Power**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The sum of the nameplate rated horsepower (hp) of all fan motors on the cooling tower. Pony motors should not be included.
<i>Units</i>	Gpm/hp or unitless if energy input ratio (EIR) is specified (If the nominal tons but not the condenser water flow is specified, the condenser design water flow shall be 3.0 gpm per nominal cooling ton.)
<i>Input Restrictions</i>	As designed, but the cooling towers shall meet minimum performance requirements in Table 110.2-G.
<i>Standard Design</i>	The cooling tower fan horsepower is 60 gpm/hp.

**Cooling Tower Design Wet-Bulb**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design wet-bulb temperature that was used for selection and sizing of the cooling tower.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed, based on the design conditions from Reference Appendix JA2 for the city most closely corresponding to local conditions.
<i>Standard Design</i>	Same as proposed design

**Cooling Tower Design Entering Water Temperature**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design condenser water supply temperature (leaving tower) that was used for selection and sizing of the cooling tower.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 85°F.
<i>Standard Design</i>	85°F or 10°F above the design wet-bulb temperature, whichever is lower

**Cooling Tower Design Return Water Temperature**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design condenser water return temperature (entering tower) that was used for

	selection and sizing of the cooling tower.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 95°F.
<i>Standard Design</i>	Set to a range of 10 F (10°F above the cooling tower design entering water temperature).

### Cooling Tower Capacity Adjustment Curve(s)

<i>Applicability</i>	All cooling towers
<i>Definition</i>	A curve or group of curves that represent the available total cooling capacity as a function of outdoor air wet-bulb, condenser water supply and condenser water return temperatures. The default curves are given as follows:

Option 1 (DOE-2 based performance curves)

(63)

$$\begin{aligned}
 t_R &= t_{cwr} - t_{cws} \\
 t_A &= t_{cws} - t_{owb} \\
 t_A &= a + b \times t_R + c \times t_R^2 + d \times FRA + e \times FRA^2 + f \times t_R \times FRA \\
 FRA &= \frac{-d - f \times t_R + \sqrt{(d + f \times t_R)^2 - 4 \times e \times (a + b \times t_R + c \times t_R^2 - t_A)}}{2 \times e} \\
 FWB &= a + b \times FRA + c \times FRA^2 + d \times t_{owb} + e \times t_{owb}^2 + f \times FRA \times t_{owb} \\
 Q_{available} &= Q_{rated} \times FWB \times \left( \frac{t_R}{10} \right)
 \end{aligned}$$

Where

$Q_{available}$	Available cooling capacity at present outside air and condenser water conditions (MBH)
$Q_{rated}$	Rated cooling capacity at CTI test conditions (MBH)
$t_{cws}$	The condenser water supply temperature (in °F)
$t_{cwr}$	The condenser water return temperature (in °F)
$t_{owb}$	The outside air wet-bulb temperature (°F)
$t_R$	The tower range (in °F)
$t_A$	The tower approach (in °F)
FRA	An intermediate capacity curve based on range and approach
FWB	The ratio of available capacity to rated capacity (gpm/gpm).

Table 59 – Default Capacity Coefficients – Cooling Towers

Coefficient	FRA	FWB
a	-2.22888899	0.60531402
b	0.16679543	-0.03554536
c	-0.01410247	0.00804083
d	0.03222333	-0.02860259
e	0.18560214	0.00024972
f	0.24251871	0.00490857

## Option 2: CoolTools performance curve (EnergyPlus)

Approach = Coeff(1) + Coeff(2)•FRair + Coeff(3)•(FRair)<sup>2</sup> + Coeff(4)•(FRair)<sup>3</sup> + Coeff(5)•FRwater +  
 Coeff(6)•FRair•FRwater + Coeff(7)•(FRair)<sup>2</sup>•FRwater + Coeff(8)•(FRwater)<sup>2</sup> + Coeff(9)•FRair•(FRwater)<sup>2</sup> +  
 Coeff(10)•(FRwater)<sup>3</sup> + Coeff(11)•Twb + Coeff(12)•FRair•Twb + Coeff(13)•(FRair)<sup>2</sup>•Twb +  
 Coeff(14)•FRwater•Twb + Coeff(15)•FRair•FRwater•Twb + Coeff(16)•(FRwater)<sup>2</sup>•Twb +  
 Coeff(17)•(Twb)<sup>2</sup> + Coeff(18)•FRair•(Twb)<sup>2</sup> + Coeff(19)•FRwater•(Twb)<sup>2</sup> + Coeff(20)•(Twb)<sup>3</sup> + Coeff(21)•Tr  
 + Coeff(22)•FRair•Tr + Coeff(23)•FRair•FRair•Tr + Coeff(24)•FRwater•Tr + Coeff(25)•FRair•FRwater•Tr +  
 Coeff(26)•(FRwater)<sup>2</sup>•Tr + Coeff(27)•Twb•Tr + Coeff(28)•FRair•Twb•Tr + Coeff(29)•FRwater•Twb•Tr +  
 Coeff(30)•(Twb)<sup>2</sup>•Tr + Coeff(31)•(Tr)<sup>2</sup> + Coeff(32)•FRair•(Tr)<sup>2</sup> + Coeff(33)•FRwater•(Tr)<sup>2</sup> +  
 Coeff(34)•Twb•(Tr)<sup>2</sup> + Coeff(35)•(Tr)<sup>3</sup>

Where

FRair – ratio of airflow to airflow at design conditions

FRwater – ratio of water flow to water flow at design conditions

Tr – tower range (deg F)

Twb – wet-bulb temperature

Coefficients for this performance curve are provided in Appendix 5.7.

## Data structure

*Input Restrictions* User may only use one of the two default curves.

*Standard Design* Use one of the two default curves.

**Cooling Tower Set Point Control**

*Applicability* All cooling towers

*Definition* The type of control for the condenser water supply. The choices are:

- Fixed
- Wet-bulb reset

A fixed control will modulate the tower fans to provide the design condenser water supply temperature at all times when possible. A wet-bulb reset control will reset the condenser water setpoint to a fixed approach to outside air wet-bulb temperature. The approach defaults to 10°F. A lower approach may be used with appropriate documentation.

*Units* List (see above)

*Input Restrictions*

As designed. If the user does not use the default control, supporting documentation is required.

*Standard Design* Fixed at the design wet-bulb temperature, as specified in Reference Appendix JA2

### Cooling Tower Capacity Control

*Applicability* All cooling towers

*Definition* Describes the modulation control employed in the cooling tower. Choices include:

- **Fluid Bypass** provides a parallel path to divert some of the condenser water around the cooling tower at part-load conditions
- **Fan Cycling** is a simple method of capacity control where the tower fan is cycled on and off. This is and is often used on multiple-cell installations.
- **Two-Speed Fan/Pony Motor**. From an energy perspective, these are the same. A lower horsepower pony motor is an alternative to a two-speed motor; the pony motor runs at part-load conditions (instead of the full sized motor) and saves fan energy when the tower load is reduced. Additional building descriptors are triggered when this method of capacity control is selected.
- **Variable Speed Fan**. A variable frequency drive is installed for the tower fan so that the speed can be modulated.

*Units* List (see above)

*Input Restrictions* As designed.

*Standard Design* Variable-speed fan for all motors of 7.5 hp or larger, unless one of the following exceptions applies:

EXCEPTION 1: heat rejection devices included as an integral part of equipment listed in Table 110.2-A through 110.2-E

### Cooling Tower Low-Speed Airflow Ratio

*Applicability* All cooling towers with two-speed or pony motors

*Definition* The percentage full load airflow that the tower has at low speed or with the pony motor operating. This is equivalent to the percentage full load capacity when operating at low speed.

*Units* Ratio

*Input Restrictions* As designed.

*Standard Design* 0.50

### Cooling Tower Low-Speed kW Ratio

*Applicability* All cooling towers

*Definition* The percentage full load power that the tower fans draw at low speed or with the pony motor operating

*Units* Ratio

*Input Restrictions* Calculated, using the as-designed flow ratio and the cooling tower power adjustment curve below..

*Standard Design* 0.25

**Cooling Tower Power Adjustment Curve**

**Applicability** All cooling towers with VSD control

**Definition** A curve that varies the cooling tower fan energy usage as a function of part-load ratio for cooling towers with variable speed fan control. The default curve is given as follows:

(64)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_R, t_A, t_{OWB})}$$

$$TWR\_FAN\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

$$P_{operating} = P_{rated} \times TWR\_FAN\_FPLR$$

where

$PLR$	Part load ratio based on available capacity (not rated capacity)
$Q_{operating}$	Present load on tower (in Btu/h)
$Q_{available}$	Tower available capacity at present range, approach, and outside wet-bulb conditions (in Btu/h).
$t_{owb}$	The outside air wet-bulb temperature (°F)
$t_R$	The tower range (°F)
$t_A$	The tower approach (°F)
$P_{rated}$	Rated power draw at CTI conditions (kW)
$P_{operating}$	Power draw at specified operating conditions (kW)

**Table 60 – Default Efficiency TWR-FAN-FPLR Coefficients – VSD on Cooling Tower Fan**

Coefficient	TWR-FAN-FPLR
a	0.33162901
b	-0.88567609
c	0.60556507
d	0.9484823

**Units** Data structure

**Input Restrictions** User may input curves or use default curves. If defaults are overridden, supporting documentation is required.

**Standard Design** Use default curves from DOE 2, given above.

**Cooling Tower Minimum Speed**

**Applicability** All cooling towers with a VSD control

**Definition** The minimum fan speed setting of a VSD controlling a cooling tower fan expressed as a ratio of full load speed.

**Units** Ratio

**Input Restrictions** As designed. The default is 0.40.

**Standard Design** Not applicable

## 5.8.4 Water-side Economizers

**Baseline Building Summary.** None of the baseline building systems use a water-side economizer.

### Water-Side Economizer Name

<i>Applicability</i>	All water-side economizers
<i>Definition</i>	The name of a water-side economizer for a cooling system
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Descriptive reference to the construction documents. The default is no water-side economizer.
<i>Standard Design</i>	No water economizer

### Water Economizer Type

<i>Applicability</i>	All water-side economizers
<i>Definition</i>	<p>The type of water-side economizer. Choices include:</p> <ul style="list-style-type: none"> <li>• None</li> <li>• Heat exchanger in parallel with chillers. This would be used with an open cooling tower is often referred to as a non-integrated economizer, because the chillers are locked out when the plant is in economizer mode.</li> <li>• Heat exchanger in series with chillers. This would be used with an open cooling tower and is often referred to as an integrated, because the chillers can operate simultaneously with water economizer operation.</li> <li>• Direct water economizer. This would be used with a closed cooling tower. In this case, a heat exchanger is not needed. This type works only as a non-integrated economizer. (also known as strainer-cycle)</li> <li>• Thermo-cycle (also known as refrigerant migration). With thermo-cycle, bypass valves allow for the flow to vapor refrigerant to the condenser and allow gravity flow of liquid refrigerant to the evaporator without use of the compressor. Only some chillers have this capability and capacity may be limited under this mode. There is no additional piping; the cooler water from the tower is brought directly to the chiller(s) and the chiller(s) respond by shutting down the compressor and relying on thermal forces to drive the refrigerant. This method is also known as “thermosiphon” since thermal gradients passively move refrigerant between the evaporator and condenser.</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	No water economizer

### Water-Side Economizer HX Effectiveness

<i>Applicability</i>	Water-side economizers with an open cooling tower
<i>Definition</i>	The effectiveness of a water-side heat exchanger at design conditions. This is defined as:

(65)

$$WSE_{eff} = \frac{t_{ea} - t_{la}}{t_{ea} - t_{ew}}$$

where

WSE<sub>eff</sub> The effectiveness of the water-side economizer coilt<sub>ea</sub> The entering coil air dry-bulb temperature (°F)t<sub>la</sub> The leaving coil air dry-bulb temperature (°F)t<sub>ew</sub> The entering coil water temperature (°F)

Units Ratio

Input Restrictions As designed. The default is 60%.

Standard Design No water economizer

**Water-Side Economizer Maximum T<sub>db</sub>**

Applicability All water-side economizers

Definition The control temperature (outside air dry-bulb temperature) above which the water-side economizer is disabled.

Units Degrees Fahrenheit (°F)

Input Restrictions As designed. Defaults to 65°F.

Standard Design No water economizer

**Water-Side Economizer Maximum CWS**

Applicability All water-side economizers

Definition The control temperature (condenser water supply temperature) above which the water-side economizer is disabled.

Units Degrees Fahrenheit (°F)

Input Restrictions As designed. Defaults to 50°F.

Standard Design No water economizer

**Water-Side Economizer CWS Setpoint**

Applicability All water-side economizers

Definition The design condenser water supply temperature for the cooling tower in economizer mode.

Units Degrees Fahrenheit (°F)

Input Restrictions As designed. Defaults to 45°F or 40°F for “Thermo Cycle.” If a strainer cycle is specified, changeover temperature from economizer to mechanical cooling shall be set at 50°F.

Standard Design No water economizer

**Water-Side Economizer Availability Schedule**

Applicability All water-side economizers

Definition

	A schedule which represents the availability of the water-side economizer
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	No water economizer

#### **Water-Side Economizer Auxiliary kW**

<i>Applicability</i>	Water-side economizers with an open tower
<i>Definition</i>	The electrical input (pumps and auxiliaries) for a dedicated pump for the chilled water side of the heat exchanger. This power is in excess of the condenser water pumps and cooling tower fans for the system during water-side economizer operation.
<i>Units</i>	KW or kW/ton
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	No water economizer

## **5.8.5 Pumps**

**Baseline Building Summary.** Hot water pumping in the baseline building (systems 1, 5, and 6) shall be modeled as a variable flow primary only system. Two-way valves are assumed at the heating coils with a modulating bypass valve at the end of the loop. The bypass valve shall open as necessary to maintain minimum flow through the boiler when the system is activated. This will establish the minimum flow through the system.

Chilled water pumping in the baseline building (system 6) is a primary system. Each chiller has its own primary and condenser water pumps that operate when the chiller is activated. The chilled water pump shall be variable speed and the condenser water pump shall be fixed speed.

**General Notes.** The building descriptors in this section are repeated for each pumping system. See the Pump Service building descriptor for a list of common pump services.

#### **Pump Name**

<i>Applicability</i>	All pumps
<i>Definition</i>	A unique descriptor for each pump
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Standard Design</i>	Same as the proposed design. If there is no equivalent in the proposed design, assign a sequential tag to each piece of equipment. The sequential tags should indicate the pump service as part of the descriptor (e.g. CW for condenser water, CHW for chilled water, or HHW for heating hot water).

#### **Pump Service**

<i>Applicability</i>	All pumps
<i>Definition</i>	The service for each pump. Choices include: <ul style="list-style-type: none"> <li>• Chilled water</li> <li>• Chilled water (primary)</li> <li>• Chilled water (secondary)</li> </ul>

- Heating water
- Heating water (primary)
- Heating water (secondary)
- Service hot water
- Condenser water
- Loop water (for hydronic heat pumps)

*Units* List (see above)

*Input Restrictions* As designed

*Standard Design* As needed by the baseline building system

### **Number of Pumps**

*Applicability* All pumps

*Definition* The number of identical pumps in service in a particular loop, e.g. the heating hot water loop, chilled water loop, or condenser water loop

*Units* Numeric: integer

*Input Restrictions* As designed

*Standard Design* There will be one heating hot water pump for each boiler, one chilled water pump, and one condenser water pump for each chiller.

### **Water Loop Design**

*Applicability* All pumps

*Definition* The heating and cooling delivery systems can consist of a simple primary loop system, or more complicated primary/secondary loops or primary/secondary/tertiary loops.

*Units* List (see above)

*Input Restrictions* As designed

*Standard Design* Assume primary loops only for heating hot water. For chilled water loops, a primary loop design is assumed s.

### **Pump Motor Modeling Method**

*Applicability* All pumps

*Definition* Software commonly models fans in one of two ways: The simple method is for the user to enter the electric power per unit of flow (W/gpm). This method is commonly used for smaller systems. A more detailed method requires a specification of the pump head, design flow, impeller and motor efficiency.

*Units* List: Power-Per-Unit-Flow or Detailed

*Input Restrictions* Either method may be used, as appropriate.

*Standard Design* Detailed

### **Pump Motor Power-Per-Unit-Flow**

*Applicability* All proposed design pumps that use the Power-Per-Unit-Flow method.

*Definition* The electric power of the pump divided by the flow at design conditions.

<i>Units</i>	W/gpm
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**Pump Design Head**

<i>Applicability</i>	All baseline building pumps and proposed design pumps that use the Power-Per-Unit-Flow method.
<i>Definition</i>	The head of the pump at design flow conditions.
<i>Units</i>	ft of water
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	For chilled water pumps, 40 ft plus an additional allowance of 0.03 ft/ton For condenser water pumps, 54 ft

**Impeller Efficiency**

<i>Applicability</i>	All pumps in proposed design that use the detailed modeling method
<i>Definition</i>	The full load efficiency of the impeller
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	70%

**Motor Efficiency**

<i>Applicability</i>	All pumps in proposed design that use the detailed modeling method
<i>Definition</i>	The full load efficiency of the pump motor
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Minimum requirement from Table 26 of the Nonresidential ACM Manual.

**Pump Minimum Speed**

<i>Applicability</i>	All two-speed or variable-speed pumps
<i>Definition</i>	The minimum pump speed for a two-speed for variable-speed pump. For two-speed pumps this is typically 0.67 or 0.5. Note that the pump minimum speed is not necessarily the same as the minimum flow ratio, since the system head may change.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The chilled water pumps for baseline buildingsystem 5 has variable speed drive In these cases the Pump Minimum Speed shall be 0.10.

**Pump Minimum Flow Ratio**

<i>Applicability</i>	Primary Chilled water pumps
<i>Definition</i>	

The minimum fraction of design flow that passes through the chiller. minimum pump speed for a two-speed for variable-speed pump. Note that the pump minimum speed is not necessarily the same as the minimum flow ratio, since the system head may change.

<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	0.3

#### **Pump Design Flow (GPM)**

<i>Applicability</i>	All pumps
<i>Definition</i>	The flow rate of the pump at design conditions. This is derived from the load, and the design supply and return temperatures.
<i>Units</i>	gpm or gpm/ton for condenser and primary chilled water pumps
<i>Input Restrictions</i>	Not a user input
<i>Standard Design</i>	The temperature change on the evaporator side of the chillers is 20 F (64 F less 44 F) and this equates to a flow of 1.2 gpm/ton. The temperature change on the condenser side of the chillers is 12 F, which equates to a flow of 2.0 gpm/ cooling ton. For hot water pumps servicing boilers, the flow rate in gpm shall be the boiler capacity in Btu/h / 15,000, which corresponds to a loop temperature drop of 30°F.

#### **Pump Control Type**

<i>Applicability</i>	All pumps
<i>Definition</i>	The type of control for the pump. Choices are: <ul style="list-style-type: none"> <li>• Fixed speed, fixed flow</li> <li>• Fixed speed, variable flow (the default, with flow control via a valve)</li> <li>• Two-speed</li> <li>• Variable speed, variable flow</li> </ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. The default is "Fixed Speed, Variable Flow" which models the action of a constant speed pump riding the curve against 2-way control valves.
<i>Standard Design</i>	The hot water and condenser water loops shall be primary loops only. The hot water pump shall be modeled as a fixed speed, variable flow pump (riding the pump curve).  The chilled water pumps shall be modeled as variable-speed, variable flow, and the condenser water pumps shall be modeled as fixed speed. The hot water pumps shall be modeled as fixed-speed, variable flow, riding the curve.

#### **Pump Operation**

<i>Applicability</i>	All pumps
<i>Definition</i>	The type of pump operation can be either On-Demand, Standby or Scheduled. On-Demand operation means the pumps are only pumping when their associated equipment is cycling, so chiller and condenser pumps are on when the chiller is on and the heating hot water pump operates when its associated boiler is cycling. Standby operation allows hot or chilled water to circulate through the primary loop of a primary/secondary loop system or through a reduced portion of a primary-only system,

assuming the system has appropriate 3-way valves. Scheduled operation means that the pumps and their associated equipment are turned completely off according to occupancy schedules, time of year, or outside conditions. Under scheduled operation, when the systems are on they are assumed to be in On-Demand mode.

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	The baseline system pumps are assumed to operate in On-Demand mode. The chilled water and condenser pumps are tied to the chiller operation, cycling on and off with the chiller, and the heating hot water pumps are tied to the boiler operation.

#### **Pump Part Load Curve**

<i>Applicability</i>	All pumps
<i>Definition</i>	A part-load power curve for the pump

(66)

$$CIRC - PUMP - FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

(67)

$$P_{pump} = P_{design} \times CIRC - PUMP - FPLR$$

where

$PLR$	Part load ratio (the ratio of operating flow rate in gpm to design flow rate in gpm)
$P_{pump}$	Pump power draw at part-load conditions (W)
$P_{design}$	Pump power draw at design conditions (W)

**Table 61 – Default Part-Load CIRC-PUMP-FPLR Coefficients – VSD on Circulation Pump**

Coefficient	CIRC-PUMP-FPLR
a	0.0015303
b	0.0052081
c	1.1086242
d	-0.1163556

<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed. Default is curve above.
<i>Standard Design</i>	Use the defaults described above.

### **5.8.6 Thermal Storage**

There are multiple ways to model thermal storage in the proposed design. The baseline building does not have thermal storage. Stratified storage tanks with a chilled water storage medium are not supported by the ACM.

**Storage Type**

<i>Applicability</i>	All thermal storage systems
<i>Definition</i>	A type of thermal energy storage (TES) that indicates the storage medium.
<i>Units</i>	List
<i>Input Restrictions</i>	Ice, Chilled Water
<i>Standard Design</i>	No thermal storage systems

**Configuration**

<i>Applicability</i>	All thermal storage systems
<i>Definition</i>	Indication of how the TES is configured and operated in relation to the chilled water cooling
<i>Units</i>	List
<i>Input Restrictions</i>	Series, Chiller Upstream Series, Chiller Downstream Parallel
<i>Standard Design</i>	No thermal storage systems

**Ice Storage Type**

<i>Applicability</i>	All thermal storage systems with Storage Type=Ice
<i>Definition</i>	Indication of the storage type for ice storage
<i>Units</i>	List
<i>Input Restrictions</i>	IceOnCoilExternal IceOnCoilInternal
<i>Standard Design</i>	No thermal storage systems

**Storage Capacity**

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal Storage Capacity of the tank
<i>Units</i>	GJ
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Tank Volume**

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal Storage Capacity of the tank
<i>Units</i>	m <sup>3</sup>
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**CHW Setpoint Schedule**

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal Storage Capacity of the tank
<i>Units</i>	Series, deg F
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Deadband Temperature Difference**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The deadband temperature difference between enabling and disabling use of the TES system for cooling
<i>Units</i>	Degrees F
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Minimum Temperature Limit**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The minimum allowed temperature of the tank, below which charging of the tank cannot occur
<i>Units</i>	Deg F
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Storage Tank Location Indicator**

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal Storage Capacity of the tank
<i>Units</i>	List
<i>Input Restrictions</i>	Schedule, Zone, or Exterior. If <i>Schedule</i> , the ambient temperature schedule must be specified. If <i>Zone</i> , the Zone name must be specified.
<i>Standard Design</i>	No thermal storage systems

**Storage Tank Heat Gain Coefficient**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer coefficient between the tank and the ambient surroundings
<i>Units</i>	W/K
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Use Side Heat Transfer Effectiveness**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer effectiveness between the use side water and the tank water
<i>Units</i>	none
<i>Input Restrictions</i>	Between 0 and 1
<i>Standard Design</i>	No thermal storage systems

**Use Side Design Flow Rate**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	Design flow rate through the use side of the storage tank
<i>Units</i>	gpm
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Source Side Heat Transfer Effectiveness**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer effectiveness between the source side water and the tank water
<i>Units</i>	none
<i>Input Restrictions</i>	Between 0 and 1
<i>Standard Design</i>	No thermal storage systems

**Source Side Design Flow Rate**

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	Design flow rate through the source side of the storage tank
<i>Units</i>	gpm
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

**Tank Recovery Time**

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	This is the time in hours for the tank to cool from 14.4°C to 9°C. This input is only used if the source side design flow rate is not specified.
<i>Units</i>	hours
<i>Input Restrictions</i>	None
<i>Standard Design</i>	No thermal storage systems

### 5.8.7 Heat Recovery Equipment

#### Heat Recovery Name

<i>Applicability</i>	All heat recovery systems
<i>Definition</i>	A name assigned to a heat recovery system. This would provide a link to the construction documents.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	No heat recovery systems

#### Heat Recovery Device Type

<i>Applicability</i>	All heat recovery systems
<i>Definition</i>	The type of heat recovery equipment. Choices include: <ul style="list-style-type: none"> <li>• Double-Bundled Chiller</li> <li>• Generator</li> <li>• Engine-Driven Chiller</li> <li>• Air Conditioning Unit</li> <li>• Refrigerated Casework</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Heat recovery systems are not included in the baseline system.

#### Heat Recovery Loads

<i>Applicability</i>	All heat recovery systems
<i>Definition</i>	The loads met by the heat recovery system. Choices include: <ul style="list-style-type: none"> <li>• Service water heating</li> <li>• Space heating</li> <li>• Process heating</li> </ul> More than one load may be selected.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not required in the baseline system.

### 5.8.8 Plant Management

Plant management is a method of sequencing equipment. Separate plant management schemes may be entered for chilled water systems, hot water systems, etc. The following building descriptors are specified

for each load range, e.g. when the cooling load is below 300 tons, between 300 tons and 800 tons, and greater than 800 tons.

#### **Equipment Type Managed**

<i>Applicability</i>	All plant systems
<i>Definition</i>	The type of equipment under a plant management control scheme. Choices include: <ul style="list-style-type: none"> <li>• Chilled water cooling</li> <li>• Hot water space heating</li> <li>• Condenser water heat rejection</li> <li>• Service water heating</li> <li>• Electrical generation</li> </ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### **Equipment Schedule**

<i>Applicability</i>	All plant equipment
<i>Definition</i>	A schedule which identifies when the equipment is in service.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Where multiple equipment is used, they shall be staged in operation.

#### **Equipment Operation**

<i>Applicability</i>	All plant equipment
<i>Definition</i>	Equipment operation can be either On-Demand or Always-On. On-Demand operation means the equipment cycles on when it is scheduled to be in service and when it is needed to meet building loads, otherwise it is off. Always-On means that equipment runs continuously when it scheduled to be in service.
<i>Units</i>	None
<i>Input Restrictions</i>	As designed; the default is On-Demand.
<i>Standard Design</i>	Assume On-Demand operation

#### **Equipment Staging Sequence**

<i>Applicability</i>	All plant equipment
<i>Definition</i>	The staging sequence for plant equipment (chillers and boilers) indicates how multiple equipment will be staged on and off when a single piece of equipment is unable to meet the load.
<i>Units</i>	Structure – this should include (a) the percent of capacity above which additional equipment is staged on; (b) the percent of capacity below which one plant equipment is staged off
<i>Input Restrictions</i>	As designed.

<i>Standard Design</i>	Compliance software shall bring up each boiler to 90 percent capacity prior to the staging of the next boiler.
	Compliance software shall bring up each chiller to 90 percent capacity prior to the staging of the next chiller.

## 5.9 Miscellaneous Energy Uses

Miscellaneous energy uses are defined as those that may be treated separately since they have little or no interaction with the conditioned thermal zones or the HVAC systems that serve them.

### 5.9.1 Water Heating

Water heating systems shall always be modeled for both the proposed design and baseline building when the proposed building is expected to have a water heating load, even if no water heating is shown on the plans or specifications for the proposed design. In such instances, an electric resistance system shall be modeled for both the proposed design and baseline building, meeting the efficiency requirements of the baseline standard.

When the construction documents show a water heating system, the layout and configuration of the baseline building system shall be the same as the proposed design, e.g. the baseline building shall have the same number of water heaters and the same distribution system.

#### 5.9.1.1 System Loads and Configuration

##### Water Heating System Name

<i>Applicability</i>	All water heating systems
<i>Definition</i>	A unique descriptor for each water heating system. A system consists of one or more water heaters, a distribution system, an estimate of hot water use, and a schedule for that use. Nonresidential buildings will typically have multiple systems, perhaps a separate electric water heater for each office break room, etc. Other building types such as hotels and hospitals may have a single system serving the entire building.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection.
<i>Standard Design</i>	The naming convention for the baseline building system shall be similar to the proposed design.

##### Water Heating Peak Use

<i>Applicability</i>	All water heating systems, required
<i>Definition</i>	<p>An indication of the peak hot water usage (e.g. service to sinks, showers, and kitchen appliances, etc.). When specified per occupant, this value is multiplied by design occupancy density values and modified by service water heating schedules to obtain hourly load values which are used in the simulation.</p> <p>Peak consumption is commonly specified as gallons per hour per occupant, dwelling unit, hotel room, patient room, or floor area. If consumption is specified in gallons per</p>

hour, then additional inputs would be needed such as supply temperature, cold water inlet temperature, etc.

It is also common to specify peak use as a thermal load in Btu/h. In the latter case, there is an implied assumption for the cold water inlet temperature, supply temperature, distribution losses, and other factors. The thermal load does not include conversion efficiencies of water heating equipment.

*Units* Btu/h or gallons/h

*Input Restrictions* Prescribed values from Appendix 5.4A.

*Standard Design* Hot water consumption or load in the baseline building shall be the same as the proposed design, except in cases where a specific measure is specified for the proposed design that will reduce water consumption. Examples of such measures include: low-flow terminal devices or controls, alternative sanitizing technologies, or heat recovery laundry or showers drains.

#### **Water Heating Schedule**

*Applicability* All water heating systems, required

*Definition* A fractional schedule reflecting the time pattern of water heating use. This input modifies the water heating peak use, described above.

*Units* Data structure: schedule, fractional

*Input Restrictions* The schedules from Appendix 5.4A shall be used.

*Standard Design* Hot water schedules for the baseline building shall be the same as the proposed design, except in cases where a specific measure is specified for the proposed design that will reduce water consumption and the impact of the measure can be best approximated through an adjustment to the schedule. In general, such measures would be addressed through an adjustment to the water heating, peak use (see above).

#### **Water Heating System Configuration**

*Applicability* All water heating systems, required

*Definition* The configuration and layout of the water heating system, including the number of water heaters; the size, location, length and insulation of distribution pipes; recirculation systems and pumps; and any other details about the system that would affect the energy model.

*Units* Data structure

*Input Restrictions* None

*Standard Design* The baseline building shall have the same configuration and layout as the proposed design.

### **5.9.1.2 Water Heaters**

This section describes the building descriptors for water heaters. Typically, a building will have multiple water heating systems and each system can have multiple water heaters, so these building descriptors may need to be specified more than once.

#### **Water Heater Name**

*Applicability* All water heaters

<i>Definition</i>	A unique descriptor for each water heater in the system. Some systems will have multiple pieces of equipment, for instance a series of water heaters plumbed in parallel or a boiler with a separate storage tank.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection.
<i>Standard Design</i>	The naming convention for the baseline building system shall be similar to the proposed design.

### **Water Heater Type and Size**

<i>Applicability</i>	All water heaters
<i>Definition</i>	<p>This building descriptor includes information needed to determine the criteria from baseline standards. The choices are listed below.</p> <ul style="list-style-type: none"> <li>• Electric water heaters (storage and instantaneous) <ul style="list-style-type: none"> <li>○ Small (<math>\leq 12</math> kW)</li> <li>○ Large (<math>&gt; 12</math> kW)</li> <li>○ Heat pump</li> </ul> </li> <li>• Gas storage water heaters <ul style="list-style-type: none"> <li>○ Small (<math>\leq 75,000</math> Btu/h)</li> <li>○ Large (<math>&gt; 75,000</math> Btu/h)</li> </ul> </li> <li>• Gas instantaneous water heaters <ul style="list-style-type: none"> <li>○ Small (<math>&gt; 50,000</math> and <math>&lt; 200,000</math> Btu/h)</li> <li>○ Large (<math>\geq 200,000</math> Btu/h), <math>&lt; 10</math> gal</li> <li>○ Large (<math>\geq 200,000</math> Btu/h), <math>\geq 10</math> gal</li> </ul> </li> <li>• Oil storage water heaters <ul style="list-style-type: none"> <li>○ Small (<math>\leq 105,000</math> Btu/h)</li> <li>○ Large (<math>&gt; 105,000</math> Btu/h)</li> </ul> </li> <li>• Oil instantaneous water heaters <ul style="list-style-type: none"> <li>○ Small (<math>\leq 210,000</math> Btu/h)</li> <li>○ Large (<math>&gt; 210,000</math> Btu/h), <math>&lt; 10</math> gal</li> <li>○ Large (<math>&gt; 210,000</math> Btu/h), <math>\geq 10</math> gal</li> </ul> </li> <li>• Gas hot water supply boiler</li> <li>• Oil hot water supply boiler</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	The water heater type shall agree with equipment specified in the construction documents.
<i>Standard Design</i>	Water heaters in the baseline system shall be the same as those in the proposed design, except when the proposed design has a heat pump water heater, in which case the baseline building system shall have an electric storage water heater.

**Rated Capacity**

<i>Applicability</i>	All water heaters
<i>Definition</i>	The heating capacity of a water heater at the rated conditions specified in DOE 10 CFR Part 430 or ANSI Z21.10.
<i>Units</i>	Thousands of British Thermal Units per hour (MBH)
<i>Input Restrictions</i>	As designed. If the loads are not met, autosize.
<i>Standard Design</i>	Autosize

**Storage Volume**

<i>Applicability</i>	Gas-fired water heaters
<i>Definition</i>	The storage volume of a gas-fired water heater. This is used in the Standby loss calculations and baseline calculations of Energy Factor.
<i>Units</i>	gallons
<i>Input Restrictions</i>	As designed. If the loads are not met, autosize.
<i>Standard Design</i>	Autosize

**Energy Factor**

<i>Applicability</i>	Equipment covered by NAECA, which includes small storage and instantaneous water heaters
<i>Definition</i>	The energy factor (EF) is the ratio of the energy delivered by the water heater divided by the energy used, in the same units. EF is calculated according to the DOE 10 CFR Part 430 test procedure, which specifies a 24-hour pattern of draws, a storage temperature, inlet water temperature, and other test conditions. These conditions result in the energy delivered for the test period. Energy inputs are measured for the same test period and the EF ratio is calculated.
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building.
<i>Standard Design</i>	<p>The EF for the baseline building system shall be determined from the CEC Appliance Efficiency Regulations. The following baseline EF applies for water heaters:</p> <p>Gas-fired storage type water heaters: <math>0.67 - 0.0019 \times V</math></p> <p>Oil-fired water heaters: <math>0.59 - 0.0019 \times V</math></p> <p>Electric storage water heaters: <math>0.97 - 0.00132 \times V</math></p> <p>Gas-fired instantaneous: <math>0.62 - 0.0019 \times V</math></p> <p>Electric instantaneous: <math>0.93 - 0.00132 \times V</math></p> <p>Heat pump water heaters: <math>0.97 - 0.00132 \times V</math></p> <p>Where V is the rated volume in gallons.</p>

**Thermal Efficiency**

<i>Applicability</i>	Oil and gas fired water heaters not covered by NAECA
<i>Definition</i>	The full load efficiency of a water heater at rated conditions expressed as a dimensionless ratio of output over input. This is also referred to as recovery efficiency.

<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	<p>Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building.</p> <p>For NAECA covered water heaters that have specified an Energy Factor but not a recovery efficiency, the default recovery efficiency is as follows:</p> <p>Gas Water Heaters: <math>\eta_{th} = 0.78</math></p> <p>Electric Water Heaters: <math>\eta_{th} = 0.97</math></p>
<i>Standard Design</i>	Baseline efficiency is set from the Appliance Efficiency Regulations

**Tank Standby Loss**

<i>Applicability</i>	Water heaters not covered by NAECA
<i>Definition</i>	The tank standby loss for storage tanks, which includes the effect of recovery efficiency.
<i>Units</i>	Btu/h for the entire tank
<i>Input Restrictions</i>	Standby loss is calculated by the following:
$STBY = 453.75 \times S \times VOL$	
where	
S	= The standby loss fraction listed in the Commission's Appliance Database of Certified Water Heaters,
VOL	= The actual storage capacity of the water heater as listed in the Commission's Appliance Database of Certified Water Heaters
<i>Standard Design</i>	

**Tank Off-Cycle Loss Coefficient**

<i>Applicability</i>	Water heaters
<i>Definition</i>	The tank standby loss coefficient (UA) for the water heater. For small water heater covered by NAECA, the loss coefficient is a derived parameter, a function of the Energy Factor and recovery efficiency
<i>Units</i>	Btu/h-deg F
<i>Input Restrictions</i>	For NAECA covered water heaters, the loss coefficient is calculated by the following:
$UA = \frac{1/EF - 1/RE}{67.5 \times \left( \frac{24}{41094} - \frac{1}{RE \cdot Pon} \right)}$	
where	
EF	= The energy factor of the rated water heater (Unitless)
RE	= The recovery efficiency of the rated water heater. If this data is not available the default shall be 0.78 for gas water heaters and 0.93 for electric water heaters.
Pon	= The input power to the water heater, in Btu/h
<i>Standard Design</i>	The baseline loss coefficient for NAECA water heaters shall be:

10 Btu/h for gas-fired water heaters

**Off Cycle Parasitic Losses**

<i>Applicability</i>	Water heater
<i>Definition</i>	The rate of parasitic losses, such as a pilot light or controls, when the water heater is not heating.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	0

**Off Cycle Fuel Type**

<i>Applicability</i>	Water heater
<i>Definition</i>	The type of fuel that serves energy using parasitic equipment, such as a pilot light or controls, when the water heater is not heating.
<i>Units</i>	List: Electricity, Gas, Oil, Propane
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

**On Cycle Parasitic Losses**

<i>Applicability</i>	Water heater
<i>Definition</i>	The rate of parasitic losses, such as a pilot light or controls, when the water heater is not heating. This may be different than off cycle losses if the flue energy is considered.
<i>Units</i>	Watts
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	0

**On Cycle Fuel Type**

<i>Applicability</i>	Water heater
<i>Definition</i>	The type of fuel that serves energy using parasitic equipment, such as a pilot light or controls, when the water heater is not heating.
<i>Units</i>	List: Electricity, Gas, Oil, Propane
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Electricity

**Water Heater Ambient Location**

<i>Applicability</i>	Water heater
<i>Definition</i>	The location of the water heater for determining losses and energy interaction with the surroundings
<i>Units</i>	List: Schedule, Zone, Outdoors
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	

Zone

**Tank Standby Loss Fraction**

<i>Applicability</i>	Title 24 Standards
<i>Definition</i>	The tank standby loss fraction for storage tanks.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	Prescribed to the value listed in the Commission's Appliance Database of Certified Water Heaters
<i>Standard Design</i>	TBD

**THE PART-LOAD CURVE PROCEDURE IN TITLE 24 CAN BE AN ALTERNATE METHOD OF SPECIFYING THE EFFECTS OF STANDBY AND PARASITIC LOSSES ON PERFORMANCE. THE PRIMARY METHOD IS TO SPECIFY A LOSS COEFFICIENT FOR THE STORAGE TANK.**

**Fuel Water Heater Part Load Efficiency Curve**

<i>Applicability</i>	Water Heating equipment for which a loss coefficient is not specified (alternate method)
<i>Definition</i>	A set of factors that adjust the full-load thermal efficiency for part load conditions. The factor is set as a curve.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	The following default curve shall be used unless detailed information is provided to justify alternative values. The default curve shall take the form of a quadratic equation as follows:

(68)

$$Fuel_{partload} = Fuel_{design} \times FHeatPLC$$

$$FHeatPLC = \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

where

$FHeatPLC$	The fuel heating part load efficiency curve
$Fuel_{partload}$	The fuel consumption at part load conditions (Btu/h)
$Fuel_{design}$	The fuel consumption at design conditions (Btu/h)
$Q_{partload}$	The water heater capacity at part load conditions (Btu/h)
$Q_{rated}$	The water heater capacity at design conditions (Btu/h)
$a$	Constant, 0.021826
$b$	Constant, 0.977630
$c$	Constant, 0.000543

For Title 24, the coefficients shall be determined by the following :

**(SEE NACM 2.6.1.1)**

$a = STBY / INPUT$

$$b = \text{INPUT}$$

$$a = \frac{STBY}{INPUT}$$

$$b = \frac{(INPUT \times RE^*) - STBY}{SRL}$$

\* or Thermal Efficiency (TE)

PLR<sub>n</sub> = Part-load ratio for the nth hour and shall always be less than 1. PLR n is calculated from the following equation:

$$PLR_n = \frac{SRL \times F_{whpl(n)}}{INPUT \times RE^*}$$

\* or Thermal Efficiency (TE)

INPUT = The input capacity of the water heater expressed in Btu/hr.

STBY = Hourly standby loss expressed in Btu/hr. For large storage gas water heaters STBY is listed in the CEC's appliance database. The value includes pilot energy and standby losses. For all other systems refer to equation N2-62.

For Boilers, Instantaneous gas or other storage type water heaters, not in the scope of Covered Consumer Products as defined in the Title 10 or the Code of Federal Regulations, Part 430;

$$STBY = 453.75 \times S \times VOL$$

where

S = The standby loss fraction listed in the Commission's Appliance Database of Certified Water Heaters,

VOL = The actual storage capacity of the water heater as listed in the Commission's Appliance Database of Certified Water Heaters,

Required inputs and standard and proposed design assumptions depend on the type of water heater and whether or not it is a DOE covered consumer product.

*Standard Design* Not applicable

#### **Water Heating Schedule**

<i>Applicability</i>	All buildings
<i>Definition</i>	An hourly normalized load schedule that defines how the water heating load varies for each hour of the year.
<i>Units</i>	Structure (set of 8760 normalized values between 0 and 1)
<i>Input Restrictions</i>	Prescribed to values in Appendix 5.5
<i>Standard Design</i>	Same as proposed design

### **5.9.1.3 Recirculation Systems**

This section describes the building descriptors for hot water recirculation systems. The baseline building has a recirculation system when the proposed design does. This is one aspect of the *water heating system configuration* (see above).

Recirculating systems shall follow the rules set forth in Appendix E of the 2013 Residential ACM Manual.

### 5.9.1.4 Water Heating Auxiliaries

#### External Storage Tank Insulation

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Some water heating systems have a storage tank that is separate from the water heater(s) that provides additional storage capacity. This building descriptor addresses the heat loss related to the external tank, which is an additional load that must be satisfied by the water heater(s).
<i>Units</i>	R-value (h-ft <sup>2</sup> -F/Btu)
<i>Input Restrictions</i>	As specified in manufacturer data and documented on the construction documents
<i>Standard Design</i>	Heat loss associated with the storage tank in the baseline building shall meet the requirements for an unfired storage tank in the baseline standards which is an insulation R-value of 12.5. The surface area and location of the storage tank shall be the same as the proposed design.

#### External Storage Tank Area

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Some water heating systems have a storage tank that is separate from the water heater(s) that provides additional storage capacity. This documents the entire exterior surface area of the tank.
<i>Units</i>	ft <sup>2</sup>
<i>Input Restrictions</i>	As specified in manufacturer specifications
<i>Standard Design</i>	Not applicable

#### External Storage Tank Location

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Location of the storage tank, used to determine the heat loss rate and energy exchange with the surroundings
<i>Units</i>	List: Schedule, Zone, Outdoors
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Not applicable

#### Heat Recovery

<i>Applicability</i>	Water heating systems that are coupled to heat recovery equipment
<i>Definition</i>	Building equipment such as air conditioners, chillers, gas fired generators, etc. produce thermal energy that may be recovered and used to heat water. The heat producing characteristics are generally defined for the equipment that is producing the heat, not the equipment that is receiving the heat (water heaters in this case). The building descriptors will vary depending on the equipment. The models for heat producing equipment need to produce output on an hourly basis so that the schedule

	of heat production and heating needs can be aligned and evaluated in the water heating model.
<i>Units</i>	Data structure: depends on the equipment producing the heat
<i>Input Restrictions</i>	There are no restrictions, other than agreement with the construction documents.
<i>Standard Design</i>	Not applicable

### **Solar Thermal**

<i>Applicability</i>	Water heating systems with a solar thermal system
<i>Definition</i>	<p>A solar thermal water heating system consists of one or more collectors. Water is passed through these collectors and is heated under the right conditions. There are two general types of solar water heaters: integrated collector storage (ICS) systems and active systems. Active systems include pumps to circulate the water, storage tanks, piping, and controls. ICS systems generally have no pumps and piping is minimal.</p> <p>Solar systems may be tested and rated as a complete system or the collectors may be separately tested and rated. SRCC OG-300 is the test procedure for whole systems and SRCC OG-100 is the test procedure for collectors. The building descriptors used to define the solar thermal system may vary with each software application and with the details of system design.</p> <p>The solar fraction shall be estimated by the f-chart procedure for solar water heating systems.</p>
<i>Units</i>	Unitless fraction
<i>Input Restrictions</i>	The solar fraction provided by the solar DHW system shall be between 0 and 1.
<i>Standard Design</i>	The baseline building has no solar auxiliary system.

### **Combined Space Heating and Water Heating**

<i>Applicability</i>	Projects that use a boiler to provide both space heat and water heating
<i>Definition</i>	A system that provides both space heating and water heating from the same equipment, generally the space heating boiler. Such systems are restricted by the baseline standards, but may be modeled in the candidate building. The restrictions are due to the misalignment of the space heating load and the water heating load. The first is highly intermittent and weather dependent, while the latter is more constant and not generally related to the weather.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	The proposed design may have a combined space and water heating system.
<i>Standard Design</i>	The baseline building shall be modeled with separate space heating and water heating systems, meeting the prescriptive requirements for each. The water heating system shall use the same fuel as the combined boiler.

## **5.9.2 Exterior Lighting**

RESERVED FOR FUTURE USE

### 5.9.3 Swimming Pools

Swimming pools must meet applicable mandatory requirements and are not required to be modeled for California Title 24 compliance or Reach.

### 5.9.4 Other Electricity Use

This set of building descriptors should be used to include any miscellaneous electricity use that would add to the electric load of the building and would be on the building meter. These energy uses are assumed to be outside the building envelope and do not contribute heat gain to any thermal zone.

#### Miscellaneous Electric Power

<i>Applicability</i>	All buildings with miscellaneous electric equipment located on the building site
<i>Definition</i>	The power for miscellaneous equipment.
<i>Units</i>	Watts (W)
<i>Input Restrictions</i>	As designed.
<i>Standard Design</i>	Same as the proposed design

#### Miscellaneous Electric Schedule

<i>Applicability</i>	All buildings with miscellaneous electric equipment located on the building site
<i>Definition</i>	The schedule of operation for miscellaneous electric equipment. This is used to convert electric power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The schedule specified for the building should match the operation patterns of the system.
<i>Standard Design</i>	Same as the proposed design

### 5.9.5 Other Gas Use

This set of building descriptors should be used to include any miscellaneous gas use that would add to the load of the building and would be on the building meter. These energy uses are assumed to be outside the building envelope and do not contribute heat gain to any thermal zone.

#### Other Gas Power

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	Gas power is the peak power which is modified by the schedule (see below).
<i>Units</i>	Btu/h-ft <sup>2</sup>
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Same as the proposed design

#### Other Gas Schedule

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The schedule of operation for commercial gas equipment. This is used to convert gas

	power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Continuous operation is prescribed.
<i>Standard Design</i>	Same as the proposed design

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## 5.10 On-Site Power Generation

Building projects may incorporate other on-site electricity generation equipment, such as cogeneration plants or fuel cells that make electricity and produce heat. Projects may also include wind turbines. These systems may be modeled in various ways and the building descriptors described below should be considered an example of one set. In all cases, the baseline building will be modeled without on-site generation equipment. If there is no thermal link between the power generation equipment and building equipment (such as heat recovery from CHP), on-site power generation can be modeled in a separate process; otherwise, it needs to be linked to the building simulation.

RESERVED FOR FUTURE USE – onsite power generation systems are not currently modeled for Title 24 compliance or reach. Qualifying solar water heating systems are specified by a solar fraction, and referenced in Section 5.9.

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## 5.11 Common Data Structures

This section describes common data structures referenced in this chapter. The data structures presented here define objects and example parameters needed to define them. The parameters described are the most common for energy simulation engines. However, other parameters or data constructs are acceptable; however, the fields used by the simulation program must be mapped to the fields used by the building descriptor..

### 5.11.1 Schedule

This data structure provides information on how equipment, people, lights, or other items are operated on an hourly basis. The ultimate construct of a schedule is an hourly time series for the simulation period, typically 8,760 hours (365 days, 24 hours/day). However, software has often built up the hourly schedule from 24-hour schedules for different day types: weekdays, Saturdays, Sundays, holidays, etc.

There are several types of schedules:

- **Temperature** schedules specify a temperature to be maintained in a space, a temperature to be delivered from an air handler, or the leaving temperature from a chiller or other equipment.
- **Fraction** schedules specify the fraction of lights that are on, the fraction of people that are in the space, the fraction of maximum infiltration, or other factors.
- **On/off** schedules specify when equipment is operating or when infiltration is occurring.
- **Time period** schedules define periods of time for equipment sequencing, utility tariffs, etc. A time period schedule typically breaks the year in to two or more seasons. For each season, day types are identified such as weekday, Saturday, Sunday and holidays. Each day type in each season is then divided into time periods.

### **5.11.2 Holidays**

A series of dates defining holidays for the simulation period. Dates identified are operated for the schedule specified for holidays.

### **5.11.3 Surface Geometry**

This data structure represents the location, size, and position of a surface. Surfaces include roofs, walls, floors, and partitions. Surfaces are typically planar and can be represented in various manners, including the following:

- Rectangular surfaces may be represented by a height and width along with the X, Y, and Z of surface origin and the tilt and azimuth
- Surfaces may also be represented by a series of vertices (X, Y, and Z coordinates defining the perimeter of a surface). More complex polygons may be represented in this manner.

### **5.11.4 Opening Geometry**

This data structure represents the location and size of an opening within a surface. The most common method of specifying the geometry of an opening is to identify the parent surface, the height and width of the opening, and the horizontal and vertical offset (X and Y coordinates relative to the origin of the parent surface). An opening can also include a recess into the parent surface, which provides shading. However, other geometric constructs are acceptable.

### **5.11.5 Opening Shade**

This data structure describes the dimensions and position of external shading devices such as overhangs, side fins, or louvers that shade the opening. Overhangs are specified in terms of the projection distance, height above the opening, and extension distance on each side of the opening.

### **5.11.6 Construction Assembly**

This data structure describes the layers that make up the construction of a wall, roof, floor, or partition. Typically, a construction consists of a sequence of materials, described from the outside surface to the inside surface.

### **5.11.7 Fenestration Construction**

This data structure describes the frame, glass, and other features of a window or skylight. Information may be defined in multiple ways, but the criteria themselves are published as a combination of U-factor, solar heat gain coefficient (SHGC), and visible light transmission (VT). Some simulation programs use more detailed methods of describing the performance of fenestration that take into account the angle of incidence of sun striking the fenestration and other factors, such as the properties of each pane and the fill. The compliance software only uses whole window performance properties (U-factor, SHGC, VT).

### **5.11.8 Material**

This data structure describes a material that is used to build up a construction assembly. Typical material properties include specific heat, density, conductivity, and thickness. Materials can also be described in

terms of their thermal resistance. The latter approach is sometimes used to approximate construction layers that are not homogeneous, such as framing members in combination with cavity insulation.

### **5.11.9 Slab Construction**

This data structure describes the composition of a slab-on-grade. The compliance model has building descriptors for the perimeter length and the F-factor, which represents the heat loss per lineal foot.

### **5.11.10 Exterior Surface Properties**

This data structure describes the characteristics of exterior surfaces. Exterior surface properties may include emissivity, reflectivity, and roughness. The first two govern radiation exchange from the surface, while the latter governs the magnitude of the exterior air film resistance.

### **5.11.11 Occupant Heat Rate**

This data structure represents the rate of heat and moisture generated by building occupants. This is typically specified in terms of a sensible heat rate and a latent heat rate. Both are specified in Btu/h.

### **5.11.12 Furniture and Contents**

This data structure represents the thermal mass effect of furniture and other building contents. This is expressed in terms of lb/ft<sup>2</sup> for the space in question.

### **5.11.13 Reference Position in a Space**

This data structure locates a reference point in a space, typically for the purposes of daylighting control. The typical construct for the reference point is a set of coordinates (X, Y, and Z) relative to the space coordinate system.

### **5.11.14 Two Dimensional Curve**

This data structure explains one parameter in terms of another. An example is a curve that modifies the efficiency of an air conditioner relative to the fraction of time that the equipment operates within the period of an hour, for example. The relationship can be expressed in terms of the X and Y coordinates of points on the curve or it can be expressed as an equation.

### **5.11.15 Three Dimensional Curve**

This data structure explains one parameter in terms of two others. An example is a curve that modifies the efficiency of an air conditioner relative to the outside air dry-bulb temperature and the wet-bulb temperature of air returning to the coil. The relationship is a three-dimensional surface and can be expressed in terms of the X and Y coordinates of points on the curve or it can be expressed as an equation.

### **5.11.16      Temperature Reset Schedule**

This data structure describes the relationship between one temperature and another. For example, the independent variable might be outside air temperature and the dependent variable is supply air temperature. In this case, a common schedule would be to set the supply air temperature at 55°F when the outside air temperature is 80°F or warmer and at 62°F when the outside air temperature is 58°F or cooler with the supply air temperature scaling between 55°F and 62°F when the outside air temperature is between 80°F and 58°F.